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13. ABSTRACT *(Maximum 200 words)*

METHODOLOGY AND RESULTS OF THE ANALYSIS OF 102 DENVER GROUND WATER SAMPLES FOR VARIOUS TARGET COMPOUNDS ARE PRESENTED. THE OBJECTIVE OF THE DENVER SOIL AND GROUND WATER PROJECT IS TO PREVENT FURTHER ENVIRONMENTAL CONTAMINATION, CONTROL/CONTAIN EXISTING CONTAMINATION, AND UNDERTAKE MITIGATIVE EFFORT AS DEEMED NECESSARY. AS PART OF THE PROBLEM DEFINITION PHASE OF THIS PROJECT A LARGE NUMBER OF DENVER WATER SAMPLES WERE COLLECTED AND ANALYZED AT BSRC. THE PURPOSE OF THIS SURVEY WAS THE CONFIRMATION OF SEMI-QUANTIFICATION OF SPECIFIC TARGET COMPOUNDS KNOWN OR SUSPECTED TO BE PRESENT IN THE WATER SAMPLES. GB/MS WAS THE METHOD OF CHOICE FOR THIS WORK; THE OVERALL METHODOLOGY BEING SIMILAR TO THAT EMPLOYED FOR PRIORITY POLLUTANT ANALYSIS OF WATER. ALSO DESIRED WAS IDENTIFICATION AND SEMIQUANTIFICATION OF ANY OTHER SIGNIFICANT COMPONENTS. IN ADDITION, PH, CONDUCTANCE, CHLORIDE ION, SULFATE ION, AND IONIC COPPER WERE DETERMINED.

14. SUBJECT TERMS
VOA, PH, CONDUCTANCE, CHLORIDE, ION, SULFATE, COPPER, RUN-OFF, WELL WATER, EFFLUENT

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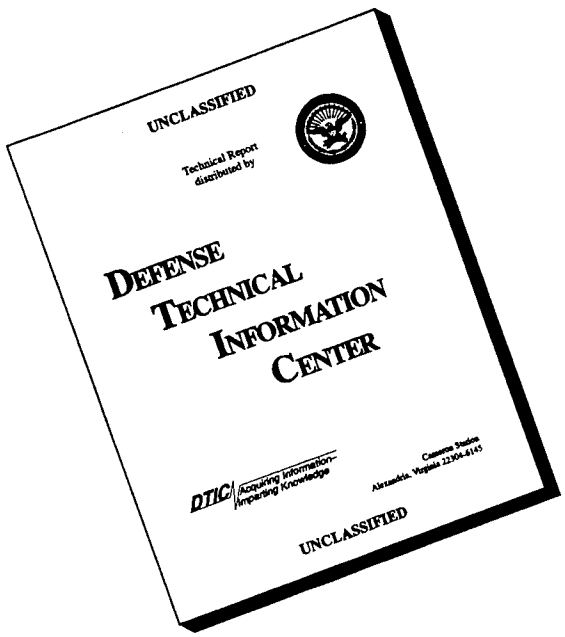

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SHELL CHEMICAL COMPANY
A DIVISION OF SHELL OIL COMPANY
P. O. BOX 2171
DENVER, COLORADO 80201

April 16, 1981

Colorado Department of Health
Water Quality Control Division
ATTN Mr. Robert Shukle, Industrial
Waste Consultant
4210 East 11th Avenue
Denver, CO 80220

Gentlemen:

Shell has conducted a survey of the groundwater on its leasehold on the Rocky Mountain Arsenal to assess groundwater quality. The analytical results from the survey as they became available have been reviewed with members of the Technical Review Committee at the last several meetings. These results have been summarized in a Technical Progress Report (M-9-81) which was recently issued by Shell Development Company. A copy of this report and a map showing well locations are attached for your information.

Yours very truly,

Original Signed By
J. H. Knaus

J. H. Knaus
Plant Manager

Attachments

cc: Commander
Rocky Mountain Arsenal
Commerce City, CO 80022

Commander
Rocky Mountain Arsenal
ATTN SARRM-TOE-C, Greg Ward, Bldg. 741
Commerce City, CO 80022

[redacted]

ANALYSIS OF DENVER WATER SAMPLES

TECHNICAL PROGRESS REPORT NO. M-9-81

By E. J. Silveira

ANALYSIS OF DENVER WATER SAMPLES

Project No. 83596.00

Denver Plant Ground Water Program

Technical Progress Report No. M-9-81

Date of Issue:

Written and Reviewed	:	E. J. Silveira
Participants	:	G. W. Campbell, D. R. Farinha, K. S. Williams, B. Calog
Approval	:	R. A. Newman
References	:	MOLR 2383, 2606

ABSTRACT

Methodology and results of the analysis of 102 Denver groundwater, samples for various target compounds are presented.

LHINK Keywords: Water, analysis, Denver, groundwater, Rocky Mountain, arsenal, Colorado, VOA, pH, conductance, chloride, ion, sulfate, copper, method, run-off, well water, effluent

ANALYSIS OF DENVER WATER SAMPLES

Introduction

The objective of the Denver Soil and Groundwater Project is to prevent further environmental contamination, control/contain existing contamination, and undertake mitigative effort as deemed necessary. As part of the Problem Definition Phase of this project a large number of Denver water samples were collected and analyzed at BSRC. The purpose of this survey was the confirmation and semi-quantification of specific target compounds known or suspected to be present in the water samples. GC/MS was the method of choice for this work; the overall methodology being similar to that employed for priority pollutant analysis of water. The list of desired target compounds is shown in Table 1. Also desired was identification and semi-quantification of any other significant components.

In addition, pH, conductance, chloride ion, sulfate ion and ionic copper were determined.

Sampling and Storage

The sampling protocol for the Denver Plant Groundwater Survey Program is as follows.

Preparation of the Wells Before Sampling Water

Wells are to be drilled at designated spots on the properties, lined with polyvinyl chloride pipe, and capped. Each well is to be numbered by stencil "Denver Plant Groundwater Well No. ___" (1 through n). Each well is to have an altitude benchmark referenced to the U.S.G.S. benchmark. Prior to each sampling of the well water, the height of the water will be determined, measured from the top of the well, and referenced to the benchmark. By use of a submersible pump (pumps which require priming or vacuum are unsuitable) and a length of Teflon tubing, about 10 volumes of water (as compared to the amount in the well casing) will be pumped out of the well. If recovery times are short and the pumping operation can be accomplished in a reasonable time frame, pumping will be done before each sampling. After each pumping operation, Denver drinking water will be used to rinse the pump. The Teflon tube should require no rinsing but may require drying by use of a piece of gauze or similar clean material.

Sampling the Water

In advance of the sampling operation, new quart bottles will be rinsed with methylene chloride and dried at 100°C. Smaller bottles or vials, 40-ml, will be supplied by Westhollow Research Center (WRC)(G. W. Stanko). All bottle caps will contain Teflon liners also to be supplied by WRC. Each bottle will be carefully stored and handled so as to avoid contamination.

The actual water sample will be obtained by bailing as follows: Immediately after pumping, the sample bottle will be placed into a weighted, stainless cage. By use of a stainless steel chain, the bottle will be quickly lowered to the bottom of the well and allowed to fill with water. The full bottle will be brought to the surface, capped, labeled with tape labels, and placed in an

ice bath. The 40-ml size bottle will be sampled in a similar manner, with care being taken to insure liquid full bottles (no air space) upon insertion of the Teflon septum. Four of the 40-ml bottles will be placed in a wide-mouth quart jar and cushioned with wads of paper. After capping, the quart jar will be placed in an ice bath. Two quart and three 40-ml samples of water shall be obtained from each well at each sampling. The full bottles will be returned to the laboratory and placed in a clean refrigerator at a temperature of 0 to 5°C (32 to 41°F); freezing must be avoided. The refrigerator will be used for no other purpose during this groundwater survey program. After the completion of the sampling for the period, or when about 20 wells have been sampled, the samples will be sent to Modesto (BSRC) by refrigerated truck or by air freight in a manner which will keep the bottles between 0 and 5°C. Upon receipt of the samples at BSRC, they will be placed in a refrigerator (0 to 5°C) pending analysis.[a)]

Sampling of the wells at Denver will be coordinated with the work load at BSRC to insure volatile analyses within two weeks of sampling. Extraction should be accomplished within one to two weeks of sampling. Extracts may be sealed in airtight vials and stored in a freezer to await analysis.

Records

A log book will be maintained for recording all sampling data. Among the entries will be the names of persons doing the sampling, weather data, height of the water in the well, any variance in the sampling procedure, and unusual events. The log book will be signed by the responsible person after each series of sampling.

A map showing the location of each well is available on request from the Denver Plant.

Instrumentation and Methodology for Volatile Organics Analysis (VOA)

The general scheme for VOA analysis is shown in flowchart form in Figure 1. Specific analytical conditions are given in Table 2.

VOA Subsampling Procedure

The VOA vial was removed from the refrigerator and allowed to come up to room temperature. The vial was opened and the tip of a 1-ml syringe (no needle attached) was inserted well below the surface and a 1.0-ml sample was drawn very slowly into the syringe. The internal standard was then added by syringe directly into the subsample. A needle was then immediately attached and the sample was injected into the sparging vessel through the septum valve.

VOA Standards

VOA reference standard solutions were freshly prepared at least once each week. The reference standard contained 20 µg/ml each of the internal standard and the target compounds in methanol solution. At least one reference standard run was made each day that samples were run. The reference standard run sample was prepared by syringe addition of 5 µl of reference standard solution to 1.0-ml of distilled water previously boiled to remove volatiles. The purpose of this reference standard run was to (1) ensure the reliability of of the analysis, and (2) to update response

a) The procedure for analysis is described separately.

factors upon which the quantification was based. A typical VOA reference standard run is shown in Figure 2.

VOA internal standard solutions were freshly prepared at least once each week. This solution contained 20 µg/ml of only the internal standard, bromochloromethane, in methanol. A 5 µl aliquot of the internal standard solution (100 ng bromochloromethane) was added by syringe to each sample and blank immediately prior to introduction to the sparging vessel. Blank runs, containing only internal standard added to distilled, previously boiled water, were made at least once each day.

VOA reference standard and internal standard solutions were kept refrigerated when not in use.

A typical gas chromatogram/mass spectrum (GC/MS) of the VOA is shown in Figure 2.

Extraction Procedure

Filtration - Prior to extraction samples were filtered through a 0.45 m Millipore membrane filter, catalogue number HAWP-047-00, covered with a Millipore glass fiber prefilter, catalogue number AP25-047-00. A Millipore filter holder with glass frit was used.

pH Adjustment

Prior to pH adjustment and extraction approximately 100-ml of each sample was retained and submitted for pH, conductance, chloride ion, sulfate ion and ionic copper determinations.

The volume of the remaining filtrate was noted and the filtrate transferred to a 2-l separatory funnel. Well samples 1A-46A were subjected to extraction without pH adjustment.

The pH of all other samples were adjusted to pH 11 with sodium hydroxide pellets. After extraction the aqueous phase was then adjusted to pH 2 with 6N HCl and reextracted.

Extraction

The aqueous solutions were extracted with 120-ml CH_2Cl_2 and the CH_2Cl_2 phase collected. The aqueous solutions were then extracted twice more with 80-ml portions of fresh CH_2Cl_2 and the three extracts combined.

Concentration

The combined CH_2Cl_2 extracts were concentrated as rapidly as possible in a Kuderna-Danish Evaporator equipped with a 3-ball Snyder column to a volume of approximately 10-ml. The extracts were then further concentrated to approximately 0.8-ml by blowdown with dry nitrogen. An aliquot of a standard solution of d_{10}-anthracene internal standard (containing 100 µg) was then added to the extract concentrates and the volume adjusted to 1.0-ml. The extracts derived from the basic solutions are the base-neutral (BN) extracts and those derived from the acidic solutions are the acid extractables (AE). Those extracts derived from solutions without pH adjustment are listed in the result table under the BN heading.

Instrumentation and Methodology for GC/MS Analysis for Extractable Organics

The general scheme for extractable organics analysis is shown in flowchart form in Figure 3. Specific analytical conditions are given in Table 3.

BN Standards

BN reference standard solutions were freshly prepared at least every 3-4 weeks. The reference standard contained 100 µg/ml each of the internal standard and the target compounds in methylene chloride solution. At least one reference standard run was made each day that samples were run. The purpose of this reference standard run was (1) to ensure the reliability of the analysis, and (2) to update response factors upon which the quantification was based. A typical reference standard run is shown in Figure 4.

BN internal standard solutions were freshly prepared at least every 3-4 weeks. This solution contained 1 mg/ml of only the internal standard, d_{10}-anthracene, in methylene chloride. A 100 µl aliquot of the internal standard solution (100 µg d_{10}-anthracene) was added by syringe to each sample extract after nitrogen blowdown.

BN reference standard and internal standard solutions were kept refrigerated when not in use.

A typical GC/MS of a BN extract is shown in Figure 4.

Samples 1A-4A, 9A, 13A, 16A, 17A, 23A-25A, 32A-34A, and 39A-41A were run on the OV-101 packed column (conditions Ⓐ in Table 3). Samples 5A-8A, 10A-12A, 14A, 15A, 18A-22A, 26A-31A, 35A-38A, 42A-46A, 16B, 24B, 40B, were run on the glass capillary column (conditions Ⓑ in Table 3). All other samples were run on the fused silica capillary column (conditions Ⓒ in Table 3).

Data Processing of GC/MS Runs

The general scheme for data processing is shown in flowchart form in Figure 5. Details of the data processing procedures and programs are to be documented in a separate report.

pH Measurement

The pH of the water samples was determined by using a Corning 110 Digital pH Meter with a Metrohm EA 121 combination glass electrode.

Conductance Measurement

Conductance was determined using a Western Instruments Model 210 Conductivity Meter with a Model 219-200 flow through cell. The calibration solution was 0.01 M KCl.

Chloride Ion Determination

Chloride ion was determined by silver nitrate titration using a Metrohm E 436 Potentiograph with a Metrohm EA 246 silver electrode.

Sulfate Ion Determination

Sulfate ion was determined turbidimetrically as $BaSO_4$ using a Hach Model 2100 Turbidimeter.

Ionic Copper Determination

Ionic copper was determined using a colorimetric method - EMS 2C14/59.

Results

The analytical results are presented in Table 4. Concentration values (in µg/l or ppb) are given for target compounds exceeding the nominal minimum detectable concentration of 10 ppb. Concentration values for other detected peaks, including tri- and tetrachlorethylene, DMK (acetone), CH_2Cl_2 and THF, are given if the peak could be tentatively identified and the concentration exceeded 200 ppb.

FIGURE 1

VOA SCHEME

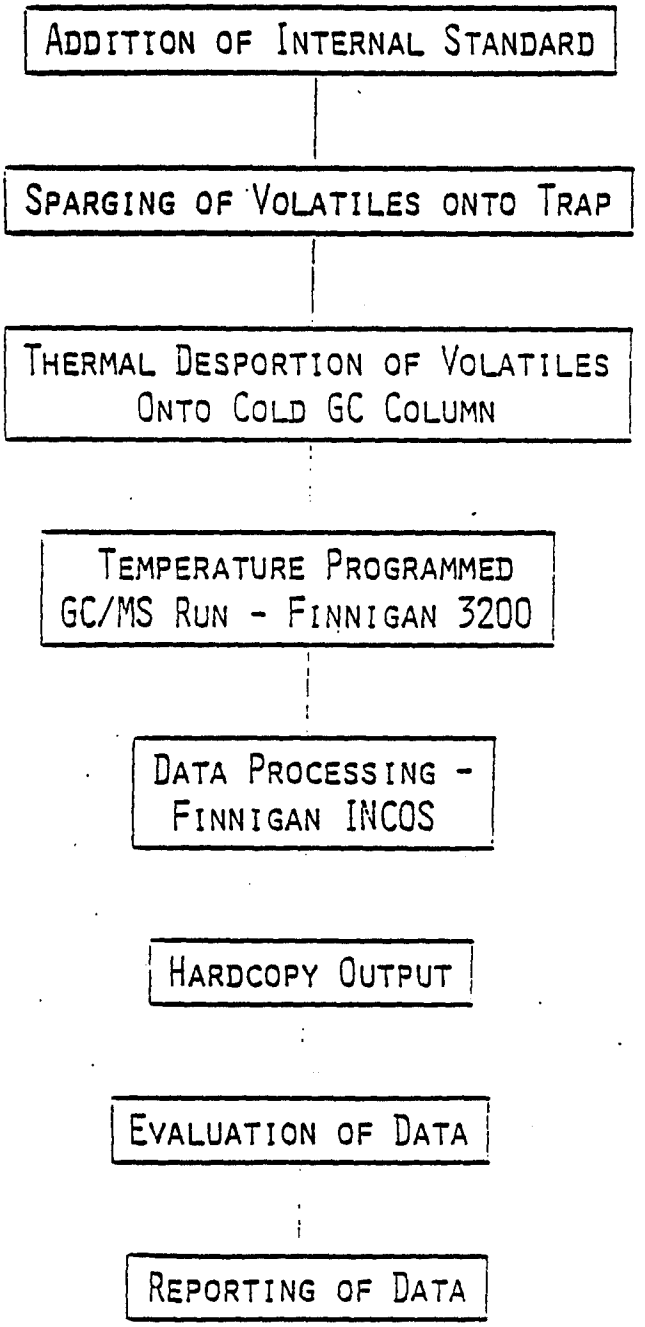


FIGURE 2

VOA STANDARDS

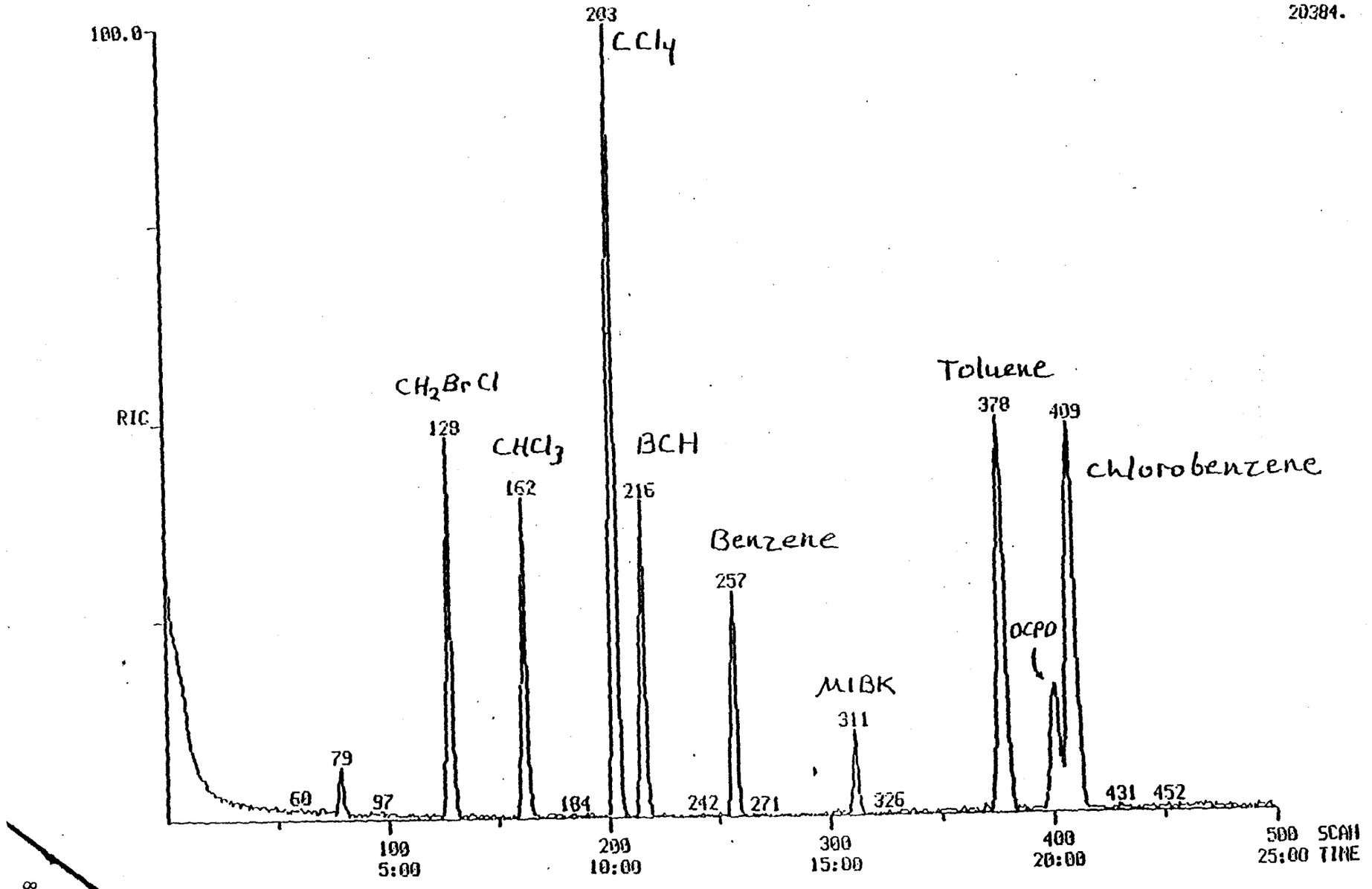
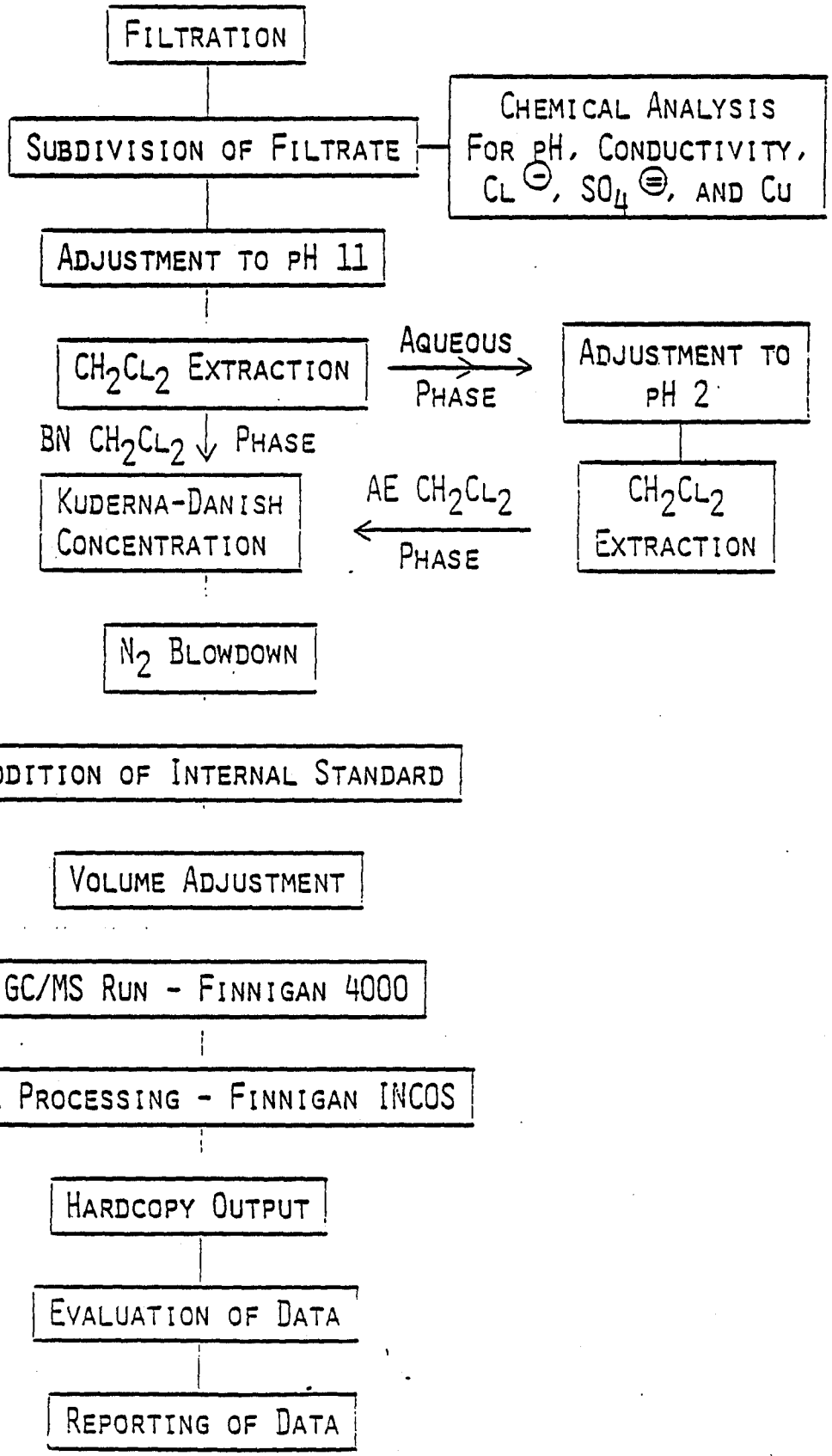


FIGURE 3

LLE SCHEME



FIGURE

BN STANDARDS

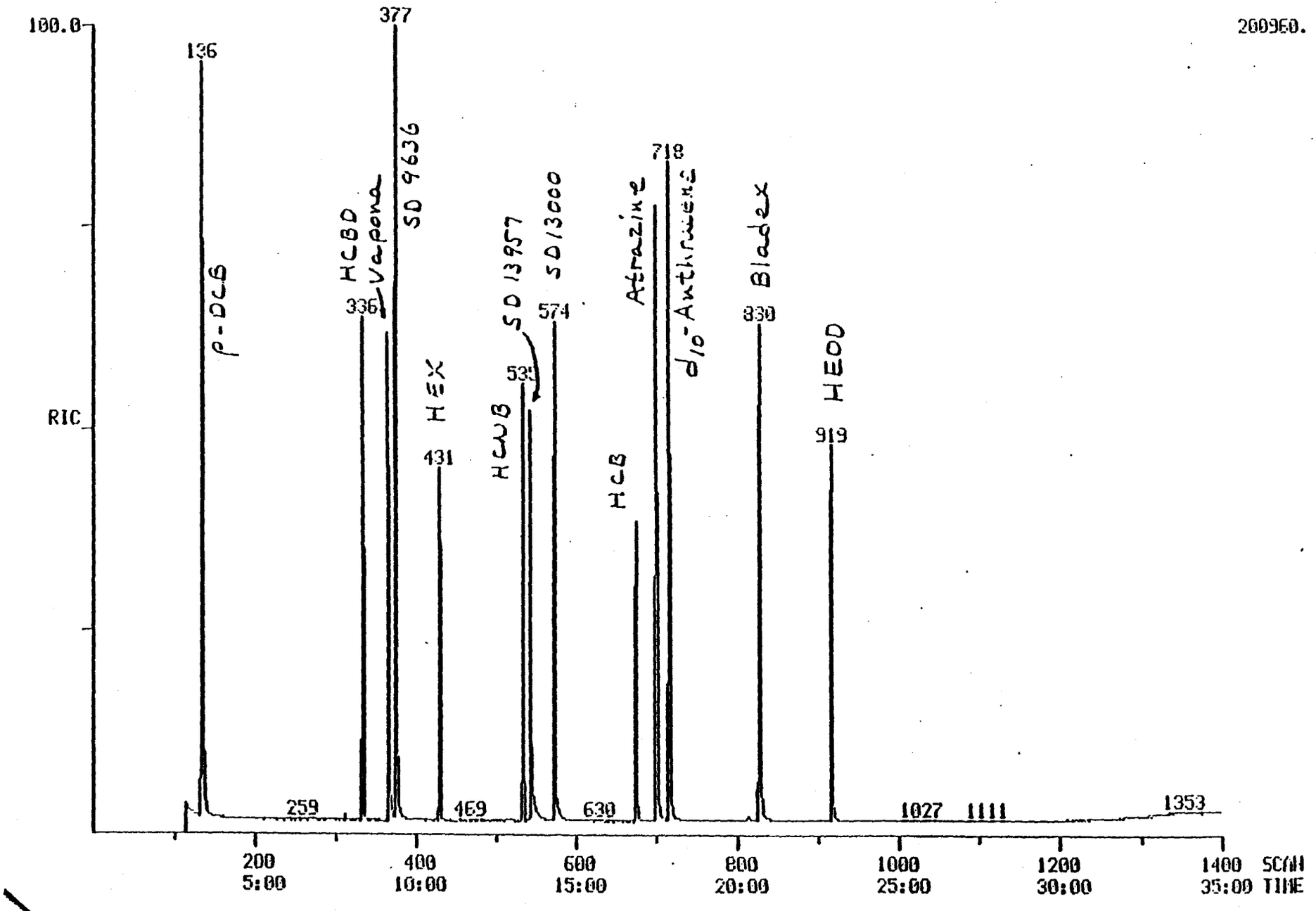
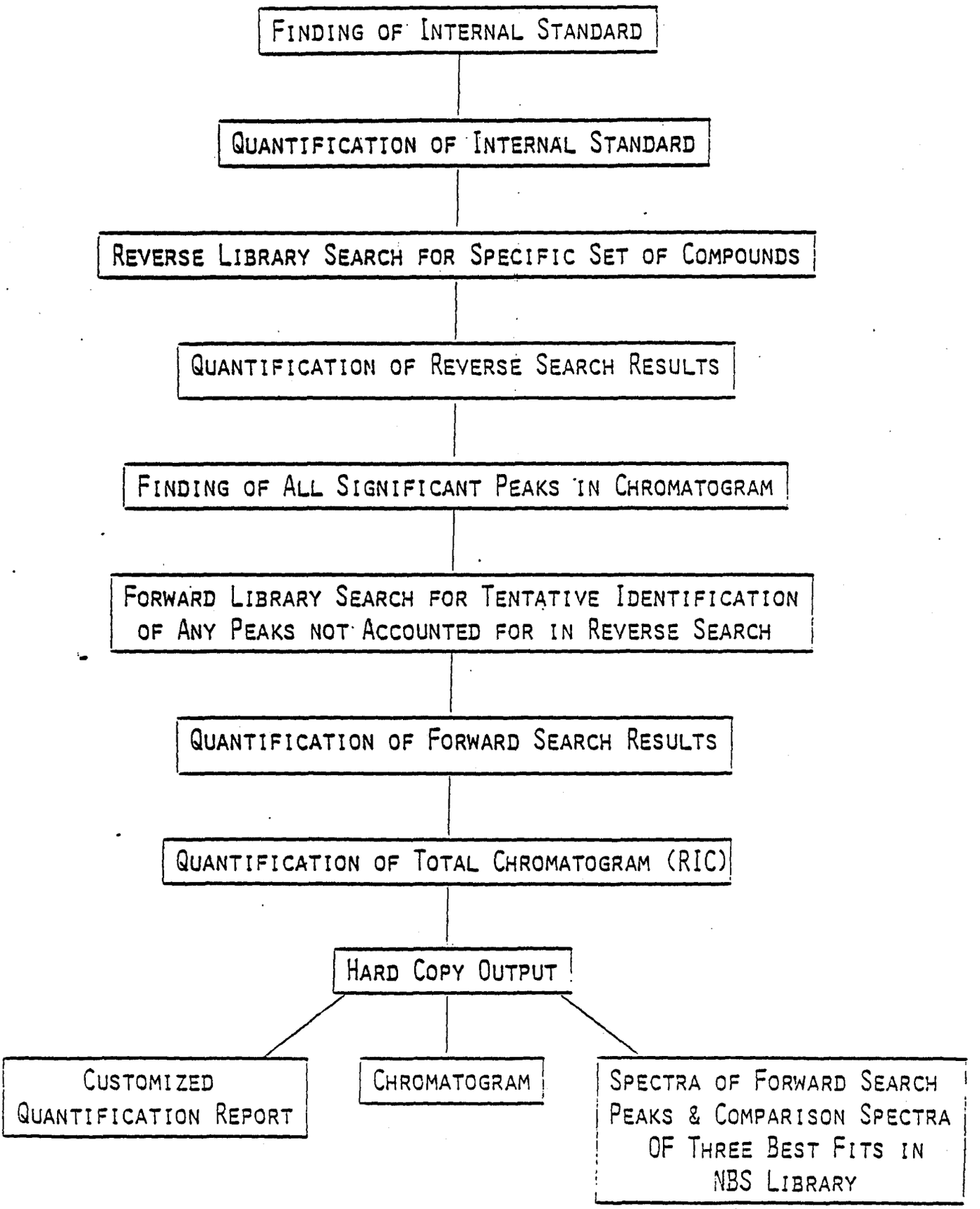
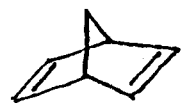
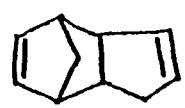


FIGURE 5

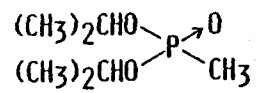
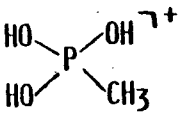
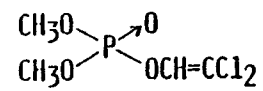
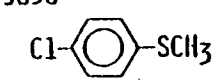
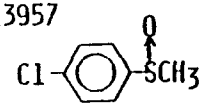
DATA PROCESSING SCHEME

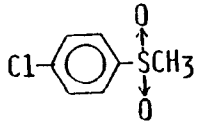
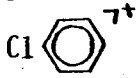
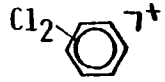
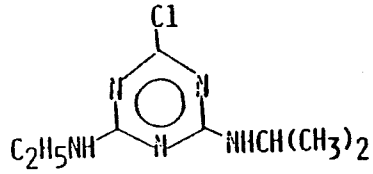
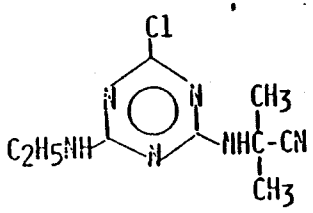
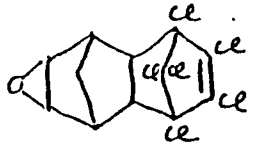


DENVER PLANT GROUNDWATER ANALYSIS

VOLATILE ORGANICS	MW	QUANTIFICATION ION	ASSIGNMENT	RELATIVE ABUNDANCE
1. CHLOROFORM	118	83	M^+ - CL	100
2. CARBON TETRACHLORIDE	152	117	M^+ - CL	100
3. BICYCLOHEPTADIENE (BCH)	92	91	M^+ - H	100
				
4. BENZENE	78	78	M^+	100
5. METHYLISOBUTYLKETONE (MIBK)	100	100	M^+	
6. TOLUENE	92	91	M^+ - H	100
7. DICYCLOPENTADIENE (DCPD)	132	66		100
				
8. CHLOROBENZENE	112	112	M^+	100

DENVER PLANT GROUNDWATER ANALYSIS

EXTRACTABLE ORGANICS	MW	QUANTIFICATION ION	ASSIGNMENT	RELATIVE ABUNDANCE
1. DICHLOROBENZENES	146	146	M^+	100
2. DIISOPROPYLMETHYLPHOSPHONATE (DIMP) 	180	97		100
3. DIBROMOCHLOROPROPANE (DBCP) $CH_2BrCHBrCH_2Cl$	234	157	M^+ - Br (P+2 ISOTOPE)	100
4. HEXACHLOROBUTADIENE	258	225	M^+ - Cl (P+2 ISOTOPE)	100
5. VAPONA 	220	109	$(CH_3O)_2P^{\nearrow O}{}^+$	
6. SD 9636 	158	158	M^+	100
7. HEXACHLOROCYCLOPENTADIENE (HEX)	270	237	M^+ - Cl (P+2 ISOTOPE)	
8. HEXACHLORONORBORNADIENE (HCNB)	296	263	M^+ - Cl (P+2 ISOTOPE)	100
9. SD 13957 	174	159	$M^+ - CH_3$	100

	MW	QUANTIFICATION ION	ASSIGNMENT	RELATIVE ABUNDANCE
10. SD 13000 	190	111		100
11. HEXACHLOROBENZENE (HCB)	282	142		100
12. ATRAZINE 	215	200	$M^+ - CH_3$	65
13. BLADEX 	240	212	$M^+ - Et$ (H TRANSFER)	45
14. DIELDRIN (HEOD) 	356	79	$C_6H_7^+$	100

OTHER COMPOUNDS WHICH HAVE BEEN DETERMINED IN SELECTED SAMPLES BY SPECIFIC RESIDUE METHODS:

1. TRIMETHYL PHOSPHATE
2. SD 15042

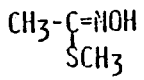


TABLE 2 - Conditions for Volatile Organics Analysis

Instrument: Finnigan 3200 GC/MS equipped with a Chemical Data Systems Model 310 Concentrator

Trapping Column: 2' x 1/8" OD stainless steel packed with Tenax 60/80 mesh

Sparge Gas: Helium

Sparge Rate: 30 ml/minute

Sparge Cycle: 12 minutes with sparging vessel at 50°C onto trapping column at room temperature

Desorb Cycle: 4 minutes at 180°C onto GC column at room temperature

Trap Bakeout Cycle: 4 minutes at 280°C

Sample Size: 1 ml or 5 ml

GC Column: 10' x 2mm ID glass column packed with 1% SP-1000 on Carbopack B, 60/80 mesh

Temperature Program: 50°C for 4 minutes, then programmed to 200°C at 10°/minute, then held at 200°C for 13.5 minutes

Injector Temperature: 200°C

Carrier: Helium at 30 ml/minute

Separator: Glass jet

Separator Temperature: 200°C

Transfer Line Temperature: 200°C

MS Mode: Electron Impact (EI)

Electron Energy: 70 eV

Electron Multiplier Voltage: Approximately 1700 V

Emission Current: 1.0 ma

Preamplifier Sensitivity: 10^{-7} a/v

Scan Range: 40-540 amu

Scan Time: 3 seconds

Scans per Run: 650

Internal Standard: 100 ng bromochloromethane

TABLE 3 - Conditions for Extractable Organics Analysis

Instrument: Finnigan 4000 GC/MS

GC Columns: (A) 6' x 2mm ID glass column packed with 3% OV-101 on Gas Chrom Q, 80/100 mesh
(B) 30m x 0.25mm ID glass WCOT capillary column coated with SE-54
(C) 30m x 0.25mm ID fused silica WCOT capillary column coated with SE-54

Temperature Program: (A) 50°C for 4 minutes, then programmed to 260°C at 10°/minute
(B) 70°C for 4 minutes, then programmed to 280°C at 8°/minute
(C) 70°C for 4 minutes, then programmed to 300°C at 8°/minute

Injector Temperature: 280°C

Carrier Gas: Helium

Flow Rate: 20 ml/minute ((A))

Injector: Modified German-Horning ((B) and (C))

Injector Flow: 20 ml/minute ((B) and (C))

Injector Pressure: 14 psi ((B) and (C))

Split Ratio: Approximately 10:1 ((B) and (C))

Separator: Glass jet ((A))

Separator Oven Temperature: 280°C

Transfer Line Temperature: 280°C

MS Mode: Electron Impact (EI)

Electron Energy: 70 e/V

Electron Multiplier Voltage: Approximately 1700 V (without conversion dynode) or approximately 1000 V (with conversion dynode at 3000 V)

Emission Current: 0.2 ma

Preamplifier Sensitivity: 10^{-7} a/v

Scan Range: 40-640 amu

Scan Time: (A) 3 seconds; (B) 2 seconds; (C) 1.5 seconds

Scan per Run: (A) 500; (B) 900; (C) 1400

Volume Injected: 2 or 3 µl

Internal Standard: 100 µg/ml d_{10}-anthracene in final extract

TABLE 4

Water Sample	$CHCl_3$	CCl_4	BCH	Benzene	MIBK	Toluene	DCPD	Chlorobenzene	dichloro benzenes	DIHP	DiCP	HCBD	Vapona	SD 9636	HEX	HCNB	SD 13957	SD 13000	HCB	Atrazine
1A				140																
2A	2900[1]		84	170	1100	44	370	110										17		
3A	2000	230	9500[1]	2300[1]	130	370	3100	5200	660											
4A	470		8000[1]	3000[1]		2600	15000[1]		33											
5A	18000[1]	160		1700[1]	15			850	150[65]		27[65]							68[65]		
6A	4200[1]		88	180	1200	48	400	120	30									27[65]		
7A	740			26																
8A	4700			100				11										17[64]		
9A	2900			55																
10A	1200	1500		370				230	85		47									
11A	12			23		15												10		
12A	250	35		42				34												
13A	20000[1]		31	1900[1]	1700	2600	560	70						170				1700		
14A	1100	1200		490				380	23[65]						33[65]			120[65]		
15A	1000[1]	33		140			720[1]	76	15[65]		20[64]							11[65]		
16A	170	19		110														41		
17A	3600[1]	1800[1]	1000[1]	1000[1]	37	740[1]		1700[1]	51		7100[1]	18						60		
18A	2900[1]	750		49				29	500[1][65]		120[65]							25[65]		
19A	2900[1]	1200	450	24		74					190							660		
20A			2600	760				49	48					17				320		59
21A	11			5800[1]		120	26	35												
22A	30			12														150		
23A	240	25		36						25										
24A	250	74	74	1200[1]	4400	1200[1]		2100[1]	3400[1]					89			17	22		
25A	1500[1]			280	650	560	120	210						730				7300		
26A	9800[1]	2500	310	930		3700[1]		420	670		30000[1]							96		
27A	6000[1]	1200	5000[1]	3700[1]		3400[1]					560[64]							73[64]		
28A				21			60											61		
29A	19			5800[1]		36	31											20		
30A	24			3900[1]																
31A																				
32A	55			8700[1]			97													
33A	86		260	23000[1]		630	2700													

All concentrations are in µg/l (ppb)

Water Sample	Bladex	HEOD	trichloro ethylene	tetrachloro ethylene	DMF	CH_2Cl_2	THF	others	BLG Total VOA	BLG Total BE	BLG Total AE	BLG Total pH	Conductase Ohm^{-1}cm^{-1} x 10^{-3}	Chloride mg/ml	Sulfate mg/ml	Copper ppm	SD 15042$^{94)}$	TUPO$^{95)}$
1A			280	660								8.2	0.55	0.033	0.034	<0.5		
2A	110		490					2) 3)				7.6	0.96	0.081	0.13	<0.5		< 1
3A			210	630	280			4)				11.9	3.0	0.18	0.17	<0.5		1
4A					6800[1)]	450	500	5) 6) 7)				12.4	10.0	0.79	0.34	<0.5		< 1
5A			990		7600[1)]	230						7.4	3.0	0.99	0.20	<0.5		2
6A			520					8) 9)				7.6	4.5	1.4	0.69	<0.5		100
7A												8.3	0.37	<0.02	0.033	<0.5		< 1
8A			480									7.3	3.8	1.1	0.36	<0.5(trace)		< 1
9A												7.5	1.4	0.076	0.12	<0.5		< 1
10A							210					8.6	0.89	0.073	0.10	<0.5		
11A							680					8.2	1.0	0.065	0.18	<0.5		
12A												8.1	2.3	0.37	0.40	<0.5(trace)		
13A		72		260	4900	1400	2700	10) 11)				9.2	3.0	0.80	0.17	<0.5	205$^{88)}$	190
14A			430	6400				12)				7.8	1.5	0.19	0.12	<0.5	< 10$^{88)}$	
15A												7.4	2.3	0.61	0.15	<0.5	1400$^{88)}$	
16A	220			21000								8.0	1.1	0.15	0.11	<0.5	15$^{88)}$	
17A				2400	1100	2200[1)]		13) 14) 15)				7.2	1.8	0.28	0.24	<0.5		70
18A							200	16)				7.9	1.4	0.27	0.12	<0.5		
19A								62)				7.8	1.6	0.18	0.30	<0.5		< 1
20A	250	13		240								7.9	0.96	0.12	0.10	<0.5		
21A							330	41)				8.1	1.3	0.14	0.23	<0.5		
22A												8.3	1.3	0.18	0.24	<0.5		
23A												8.1	0.65	0.020	0.044	<0.5		
24A			790	340	2700[1)]			17) 18) 19) 63)				8.0	1.0	0.17	0.10	<0.5		
25A				230	980[1)]	300		20) 21) 22)				7.3	14.0	1.9	0.72	<0.5		140
26A					3200	690		36) 37) 38) 39) 40)				7.5	2.3	0.60	0.11	<0.5		
27A			510	400								7.3	1.4	0.28	0.24	<0.5		80
28A								78)				7.6	2.8	0.033	0.42	<0.5		
29A												8.3	0.89	0.054	0.083	<0.5		
30A							240					8.4	0.96	0.14	0.072	<0.5		
31A							220					7.9	1.0	0.056	0.26	<0.5		
32A								23) 24) 25) 26) 27)				8.1	0.96	0.020	0.14	<0.5		
33A								79) 80) 81) 82) 83)				7.8	1.1	0.043	0.26	<0.5		

All concentrations are in µg/l (ppb)

Water Sample	$CHCl_3$	CCl_4	BCH	Benzene	MIBK	toluene	DCPD	Chlorobenzene	dichloro benzenes	DIMP	DBCP	HCBD	Vapona	SD 9639	HEX	HCNB	SD 13957	SD [illegible]	[illegible]	Atrazine
34A	32			13000[1)]		270	240	440												
35A	220		34	28000[1)]			56	1600	15											
36A	100	13	160	16000[1)]			220	1000	15											
37A			240	72		20	3700													
38A			16	5300[1)]		18	1100													
39A	110		1000[1)]	850[1)]		1000[1)]	1600[1)]													
40A				510[1)]		360	45													
41A				480[1)]		810[1)]	150													
42A	77		11	5600[1)]		17	28	1100	12											
43A	46	120		44																
44A	26						270			24										
45A	47	16		11																
46A																				
47A																				
48A			720	3200[1)]		150	1500[1)]													
49A				12000[1)]		390	130													
50A			1100	5900[1)]		690	2400[1)]													
51A																				
52A			300	6100[1)]		1800														
53A																				
54A			140	9600[1)]		840	2500													
55A			39	6900[1)]		1200	430													
56A			900	12000[1)]		3500[1)]	2000													
57A			620	11000[1)]																
58A			92	19000[1)]		3000[1)]	400													
59A				18000		140	110													
60A				74																
61A				12000[1)]		51	120													
62A	88			23000[1)]		56		940										25		
63A	120		130	8500[1)]				340												
64A	200		33	5600[1)]			130	310										14		
65A			300	37000[1)]		370		67												

All concentrations are in µg/l (ppb)

Water Sample	Dieldrin	HEOD	trichloro ethylene	tetrachloro ethylene	DMK	CH_2Cl_2	THF	Others	RLC Total VOA	RLC Total BN	RLC Total AE	pH	Conductance Ohm^{-1}Cm^{-1} x 10^{-3}	Chloride mg/ml	Sulfate mg/ml	Copper ppm	SD 15042 μM)	TUPO 95)
34A								28) 29) 30) 31) 32)				7.9	1.4	0.19	0.20	<0.5	
35A												8.0	1.4	0.17	0.25	<0.5		
36A												8.3	1.7	0.17	0.42	<0.5		
37A												8.4	0.58	<0.01	0.035	<0.5		
38A												7.6	3.2	0.074	1.2	<0.5		
39A								33)				8.0	2.2	0.60	0.20	<0.5		
40A								34)				7.6	2.6	0.20	0.72	<0.5		
41A								35)				8.1	2.3	0.65	0.17	<0.5		
42A												8.0	2.5	0.30	0.76	<0.5		
43A			300									8.4	0.69	0.043	0.072	<0.5		
44A												7.6	2.2	0.65	0.11	<0.5		
45A												8.0	0.76	0.066	0.086	<0.5		
46A												7.7	0.42	0.048	0.069	<0.5		
47A										180		7.6	1.7	0.26	0.43	<0.5		
48A							650	42) 43)	22000	3900		7.7	0.85	0.056	0.12	<0.5		
49A				680			580	44) 45) 46) 47)	53000	1400		7.9	0.98	0.074	0.15	<0.5		
50A							360	56) 57) 58)	37000	10000		8.0	0.88	0.068	0.11	<0.5		
51A							230		1100	150		7.4	3.3	0.083	0.68	<0.5		
52A								55)	27000	62000		7.3	1.2	0.14	0.19	<0.5		
53A																		
54A							3700		48000	1500		7.0	1.8	0.16	0.57	<0.5		
55A							880	53) 54)	94000	350		7.7	2.4	0.62	0.22	<0.5		
56A								52)	66000	7900		7.2	2.8	0.86	0.18	<0.5		
57A									51000	450		7.2	2.6	0.78	0.16	<0.5		
58A								51)	88000	640		7.5	2.6	0.77	0.19	<0.5		
59A							340	50)	75000	230		7.7	2.6	0.77	0.19	<0.5		
60A							1600		1800	130		7.7	1.0	0.12	0.16	<0.5		
61A							3900		46000	220		7.7	1.8	0.38	0.23	<0.5		
62A			2800						85000	310		7.2	2.2	0.25	0.82	<0.5		
63A							12000	49)	44000	580		7.5	1.2	0.13	0.19	<0.5		
64A									15000	1100		7.8	1.4	0.13	0.26	<0.5		
65A								48)	150000	11000		7.4	1.3	0.12	0.27	<0.5		

All concentrations are in µg/l (ppb)

Water Sample	CHCl3	CCl4	BCH	Benzene	MIBK	toulene	DCPD	Chlorobenzene	dichloro benzenes	DIMP	EBCP	HCBD	Vapona	SD 9636	HEX	HCNB	SD 13957	SD 13990	HCB	Atrazine
72A							110	15										110		
73A				500	94	26	76	68												
74A					870			83	11											
75A	38			1500	1700			270	16											
76A					300															
77A	440				220															
78A	12																			
79A				43	3700			1200	51									12		
80A							18											41		
81A					70															
82A	230	20		3600[1]				130	15											
83A	670	20		15000	35			270	15											
84A				3900	470															
85A																				
86A																				
87A																				
88A			680	3600[1]	210	17	75										68	12		
89A			2600[1]	5400[1]	370	3600[1]	2500													
90A	67	420		36	1500						21									
91A	6200[1]	4900[1]		100	450	530			880	65	560[1]			480			180	1400		
92A	1900	6300[1]		600	690	18		16						95			32			
93A	120	280			100									310			2900			41
94A	380	33					320													40
16B	270	19		48														34		19
24B	440	180	180	2100[1]	13000[1]	1900[1]		7200[1]	29											
37B			180				2200											11		
38B			13	1800[1]		13	1200													
40B				13000[1]		790[1]		170	21000[1]					76				15		
52B			2100[1]	12000[1]	11	7500[1]	2600										63	26		
55B				2100[1]		600	58													90
58B			160	4000[1]		3800[1]	270													26

All concentrations are in pg/l (ppb)

Water Sample	Eladex	HEOD	trichloro ethylene	tetrachloro ethylene	DMK	CH_2Cl_2	THF	Others	RLC Total VOA	BN	AE	pH	Conductage Ohm^{-1}cm^{-1} x 10^{-3}	Chloride mg/ml	Sulfate mg/ml	Copper ppm	SD 15402 94)	TUPO 95)
72A							660		760	60	84	7.3	1.5	0.21	0.17	<0.5		
73A									1600	110	170	7.2	1.5	0.18	0.16	<0.5		
74A							640		2000	250	76	7.3	1.7	0.24	0.18	<0.5		
75A							1100		4500	170	230	7.0	4.1	1.5	0.39	<0.5		
76A							200		790	79	73	7.5	0.96	1.4	0.10	<0.5		
77A							420		1300	120	150	7.1	4.5	1.8	0.10	<0.5		
78A									640	77	92	7.4	3.6	1.2	0.23	<0.5		
79A							2600		7200	360	51	7.3	3.1	0.94	0.27	<0.5		
80A									1100	220	60	7.7	1.4	0.15	0.15	<0.5		
81A									790	210	85	7.4	1.3	0.13	0.15	<0.5		
82A									2300	79	63	7.3	1.7	0.21	0.31	<0.5		
83A									29000	670	260	7.1	2.9	0.62	0.75	<0.5		
84A							360		5400	94	91	7.6	1.1	0.16	0.17	<0.5		
85A							230		860	76	75	7.8	0.81	0.08	0.08	<0.5		
86A									86	110	58	7.5	0.83	0.08	0.07	<0.5		
87A									90	33	110	7.8	0.90	0.10	0.10	<0.5		
88A							530	84)	19000	1200	220	7.6	1.0	0.14	0.09	<0.5		
89A								61)	19000	25000	3400	8.0	0.64	0.06	0.07	<0.5		
90A							660		4000	330	100	7.6	2.2	0.44	0.43	<0.5		
91A						2300[1]		89)	18000	8800	3000	7.4	2.1	0.40	0.43	<0.5		
92A									11000	260	100	7.7	1.9	0.29	0.37	<0.5		
93A	27						690		1500	730	190	7.7	2.1	0.36	0.39	<0.5		
94A	350								14000	930	38	7.1	7.0	3.3	0.25	<0.5		
16B	260			20000[1]						970	1100	7.9	1.3	0.24	0.09	<0.5		
24B			2000	990	7400[1]			68) 69)		470	760	7.7	0.99	0.19	0.09	<0.5		
37B										38000	10000	7.8	0.64	<0.01	0.03	<0.5		
38B									3500	980	2700	7.0	3.6	0.07	1.2	<0.5		
40B								70) 71) 72) 73) 74) 75) 76)		26000	1000	7.7	3.3	0.40	0.74	<0.5		
52B								67)	55000	170000	35000	7.8	1.1	0.13	0.16	<0.5		
55B							200		55000	2500	760	7.4	2.5	0.65	0.19	<0.5		
58B								66)	100000	4600	1700	7.2	2.5	0.78	0.15	<0.5		

All concentrations are in µg/l (ppb)

Water Sample	$CHCl_3$	CCl_4	HCH	Benzene	MIBK	Toulene	DCPD	Chlorobenzene	dichloro benzenes	DIMP	DBCP	HCBD	Heptena	Cp 1636	HEX	HCNB	SD 33957	SD 33950	HCB	Atrazine
59B			12	13000[1]		270	89													14
61B				9400[1]																16
65B			190	3700[1]		180		32												
77B	810	520																		600
78B	23			44																540
79B				10				1200												
80B		21					38											21		520

Water Sample	Bladex	HEOD	trichloro ethylene	tetrachloro ethylene	MIK	CH_2Cl_2	MF	others	RLC Total VOA	BN	AE	pH	Conductase Ohm^{-1}cm^{-1} x 10^{-3}	Chloride mg/ml	Sulfate mg/ml	Copper ppm	TUPO 95)	SD 154029 6)
59B									73000	1300	820	7.7	2.5	0.78	0.16	<0.5		
61B									60000	150	230	7.3	1.8	0.55	0.18	<0.5		
65B									210000	30000	14000	93)	93)	93)	93)	93)		
77B							230		1200	550	220	7.3	4.2	1.7	0.10	<0.5		
78B									450	450	300	7.6	2.7	0.91	0.15	<0.5		
79B									1800	260	250	7.5	2.8	0.85	0.24	<0.5		
80B									750	610	200	7.7	1.3	0.16	0.13	<0.5		

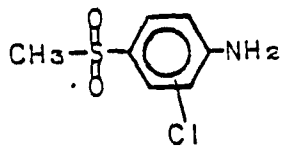
All concentrations are in µg/l (ppb)

Footnotes to Table 4

1) At least one ion in spectrum saturated; actual concentration probably greater.
2) Dimethyldisulfide 3600[1)]
3) 1,2-bis(methylthio)ethane 560
4) Dichloroethene 280
5) Cyclopentene 1900
6) Cyclopentadiene 400
7) Methyl cyclohexane 500
8) Dimethyldisulfide 4200[1)]
9) 1,2-bis(methylthio)ethane 590
10) Methyl cyclohexane 250
11) Ethyl benzene 4500
12) Hexachloroethane 1800
13) Dichloropropene 210
14) Bromochloropropene 310
15) Ethyl benzene 630
16) Bromodichloro methane 520
17) 2-propanol 360
18) Dichloroethene 300
19) Methyl cyclohexane 300
20) Ethyl benzene 340
21) Methoxy benzene 440
22) Dimethyl disulfido 1200[1)]
23) Cyclopentene 360
24) Cyclohexane 260
25) Hexane 400
26) Methyl cyclohexane 450
27) Ethyl benzene 490
28) Methyl cyclopentane 430
29) Dichloropropane 3800
30) Hexane 260
31) Methyl cyclohexane 420
32) Trichloropropane 370
33) Ethyl benzene 1900
34) Thiophene 200
35) 2-butanone 250
36) 2-butanone 440
37) Bromodichloromethane 1300
38) Bromochloropropene 1200
39) Bromochloropropane 320
40) Trichloroethanol 670
41) Methyl cyclohexane 200
42) Cyclopentene 380
43) Methyl cyclohexane 220
44) Cyclopentene 270
45) Methyl cyclohexane 490
46) Hexane 240
47) Methyl cyclohexane 390
48) Thiophene 320
49) Dichloropropane 380
50) Ethyl benzene 200
51) Ethyl benzene 440

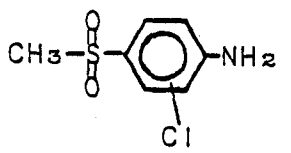
All concentrations are in µg/l (ppb)

52) Dipropyl ether 250
53) Thiophene 240
54) Ethyl benzene 210
55) dipropyl ether 360
56) Methyl cyclopentane 590
57) Methyl cyclohexane 540
58) Ethyl benzene 730
59) Bromodichloromethane 8700[1)]
60) Dibromochloromethane 450
61) Ethyl benzene 400
62)



MW 205 320

63) Dibenzyl ether 350
64) From packed column BN run
65) From capillary column BA run
66) Ethyl benzene 240
67) Ethyl benzene 1000
68) Dichloroethylene 970
69) Methyl cyclohexane 580
70) Carbon disulfide 360
71) Cyclopentene 230
72) Cyclohexane 210
73) Thiophene 550
74) Methyl cyclohexane 610
75) Ethyl benzene 310
76) Diphenyl ether 380
77) VOA sample taken from quart jar
78)



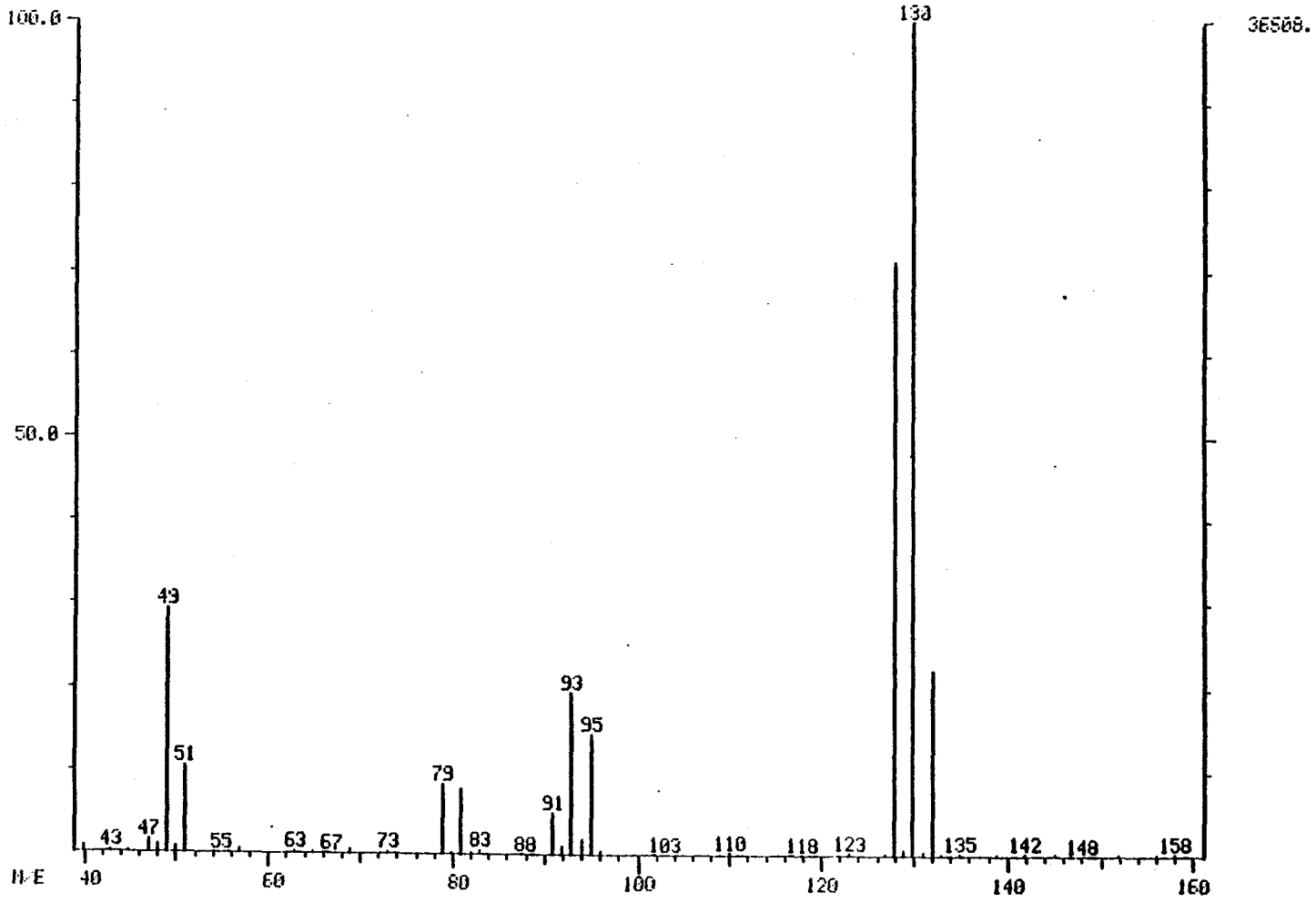
MW 205 250

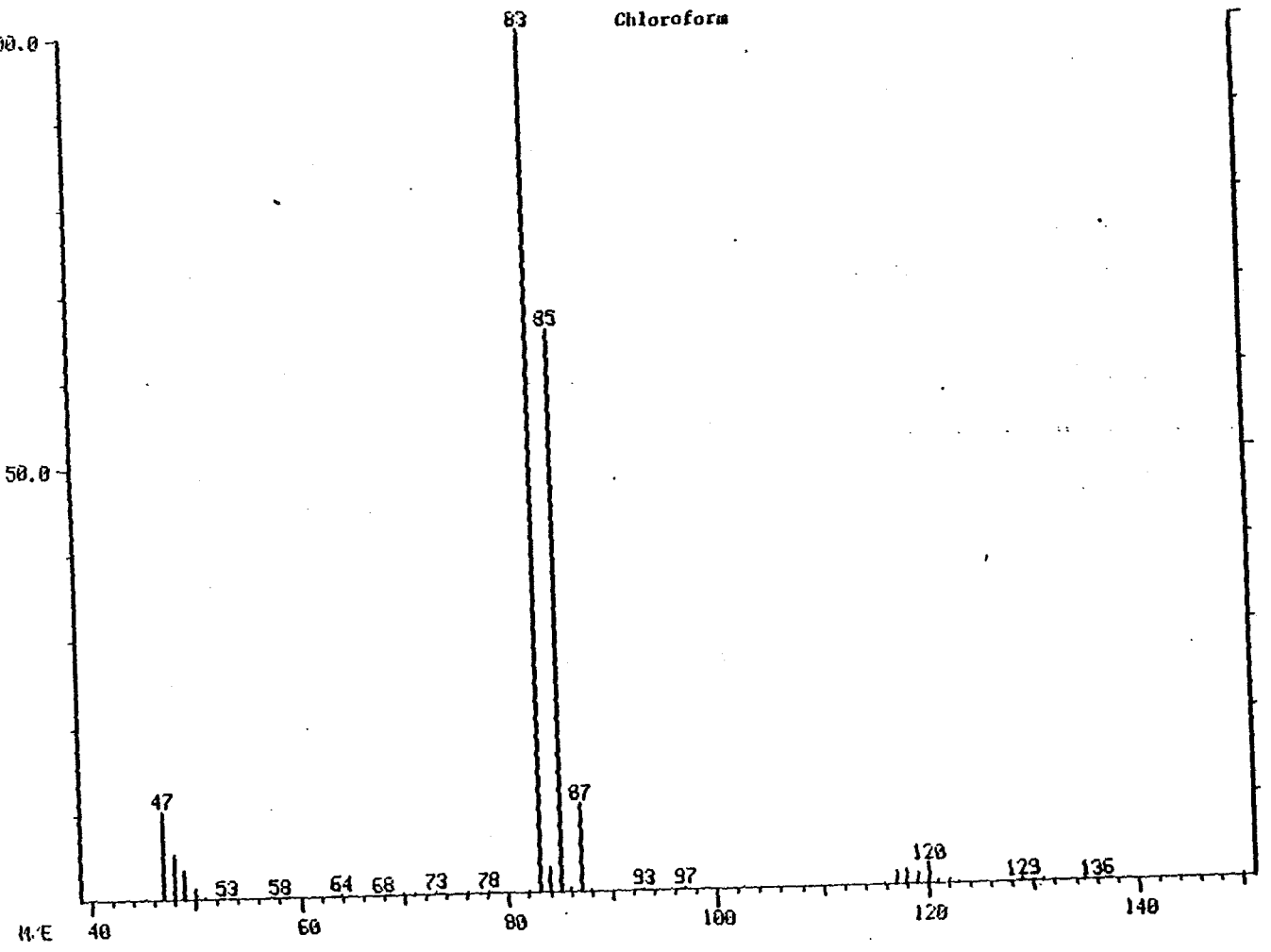
79) Cyclopentene 360
80) Cyclohexane 260
81) Hexane 400
82) Methyl cyclohexane 450
83) Ethyl benzene 490
84) Dipropyl ether 320
85) Sample lost
86) RIR-24-642-79
87) RIR-24-643-79
88) Average of two determinations
89) Trichlorophenol 910

All concentrations are in µg/l (ppb)

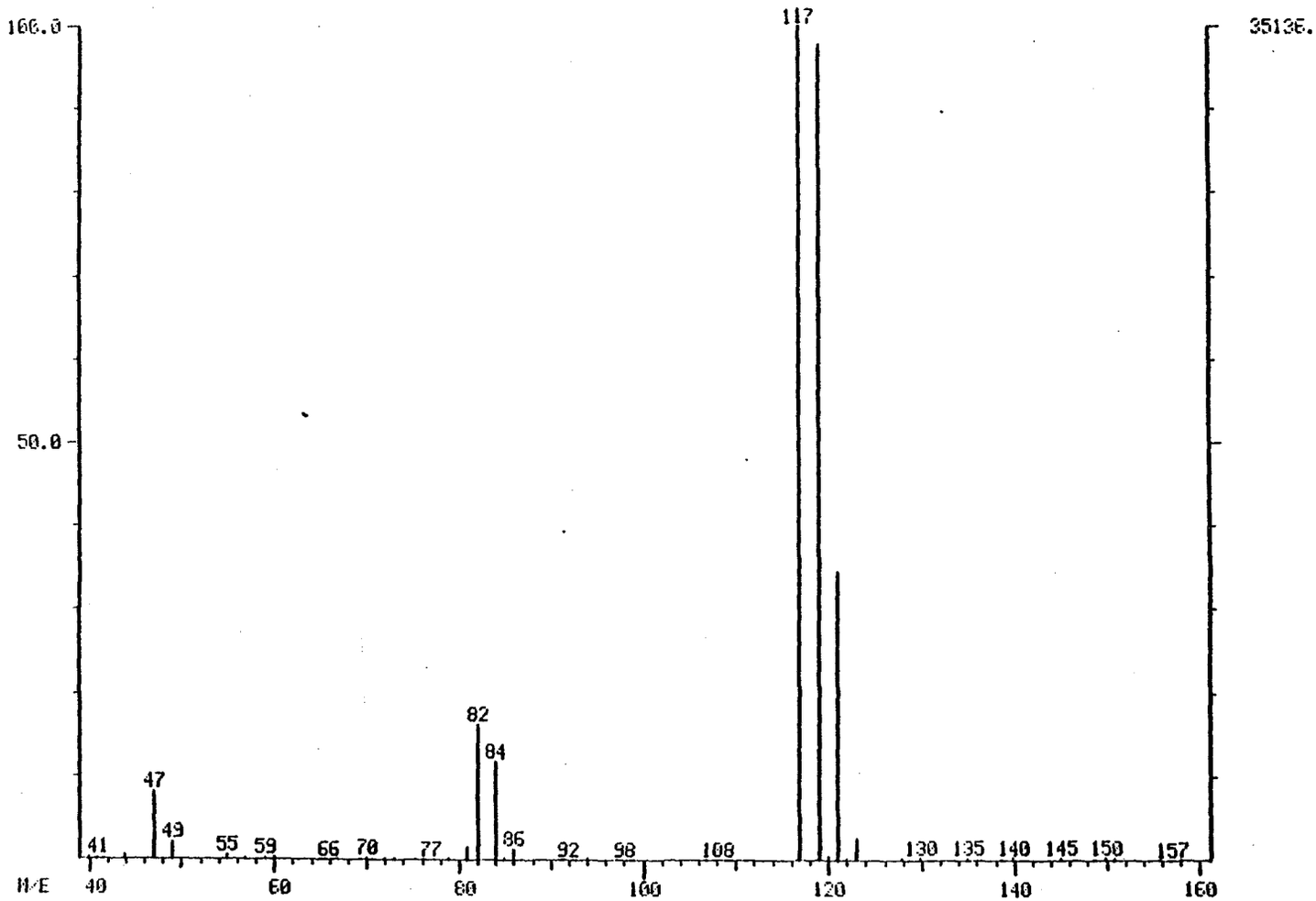
Bromochloromethane

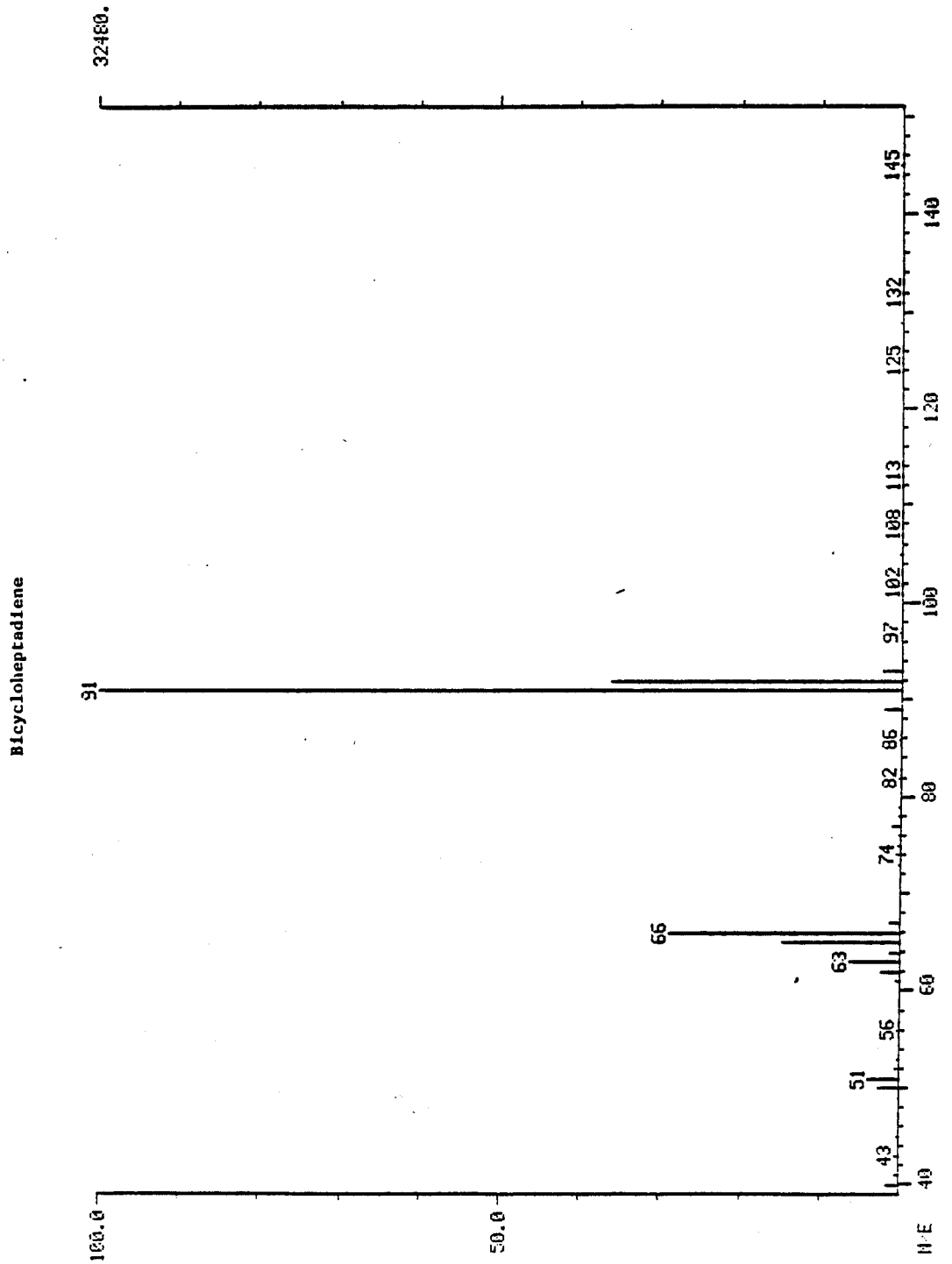
Internal Standard

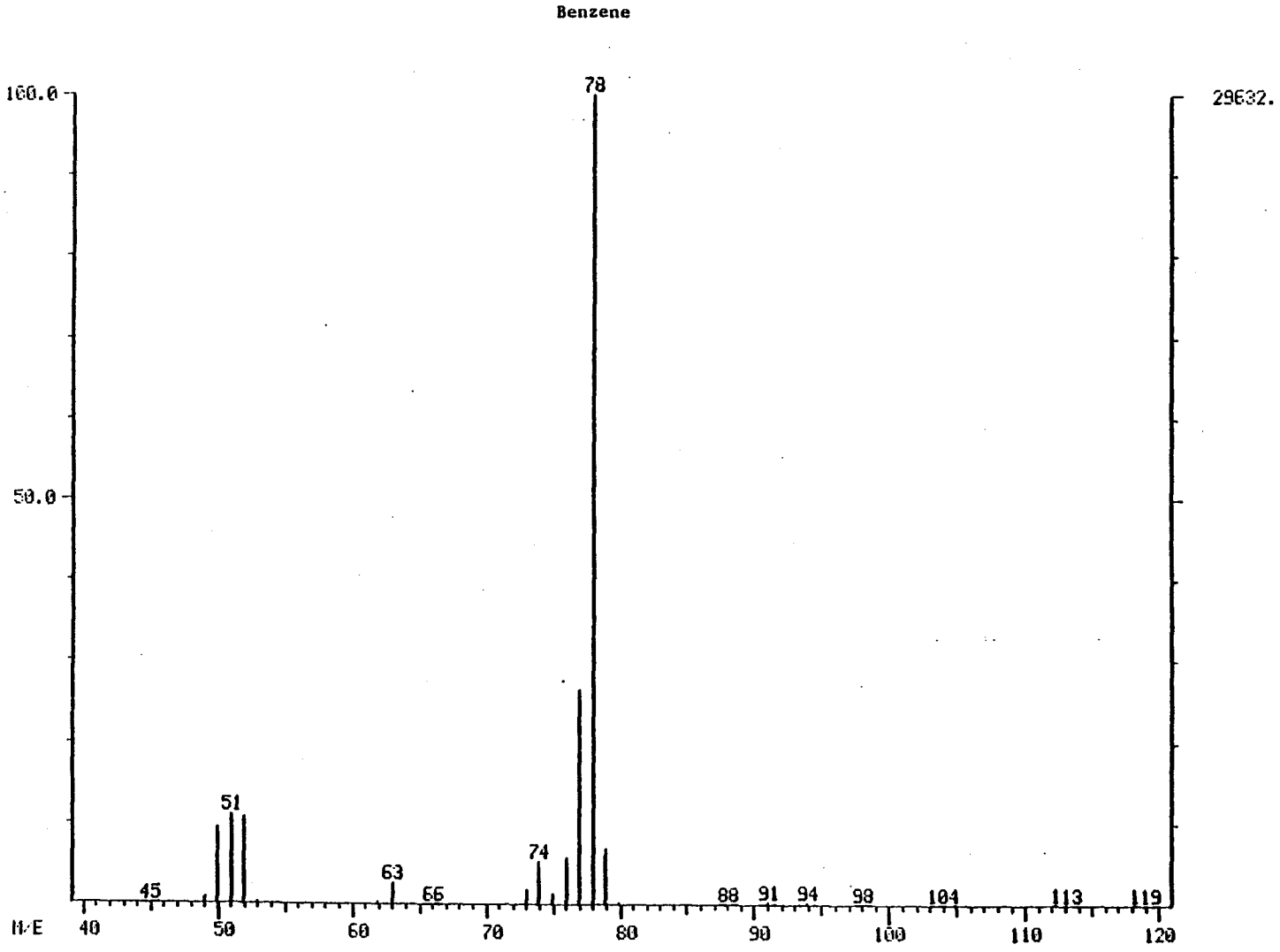



83
Chloroform
20032.
100.0
50.0
85
87
47
53
58
64
68
73
78
93
97
120
129
136
M/E
40
60
80
100
120
140

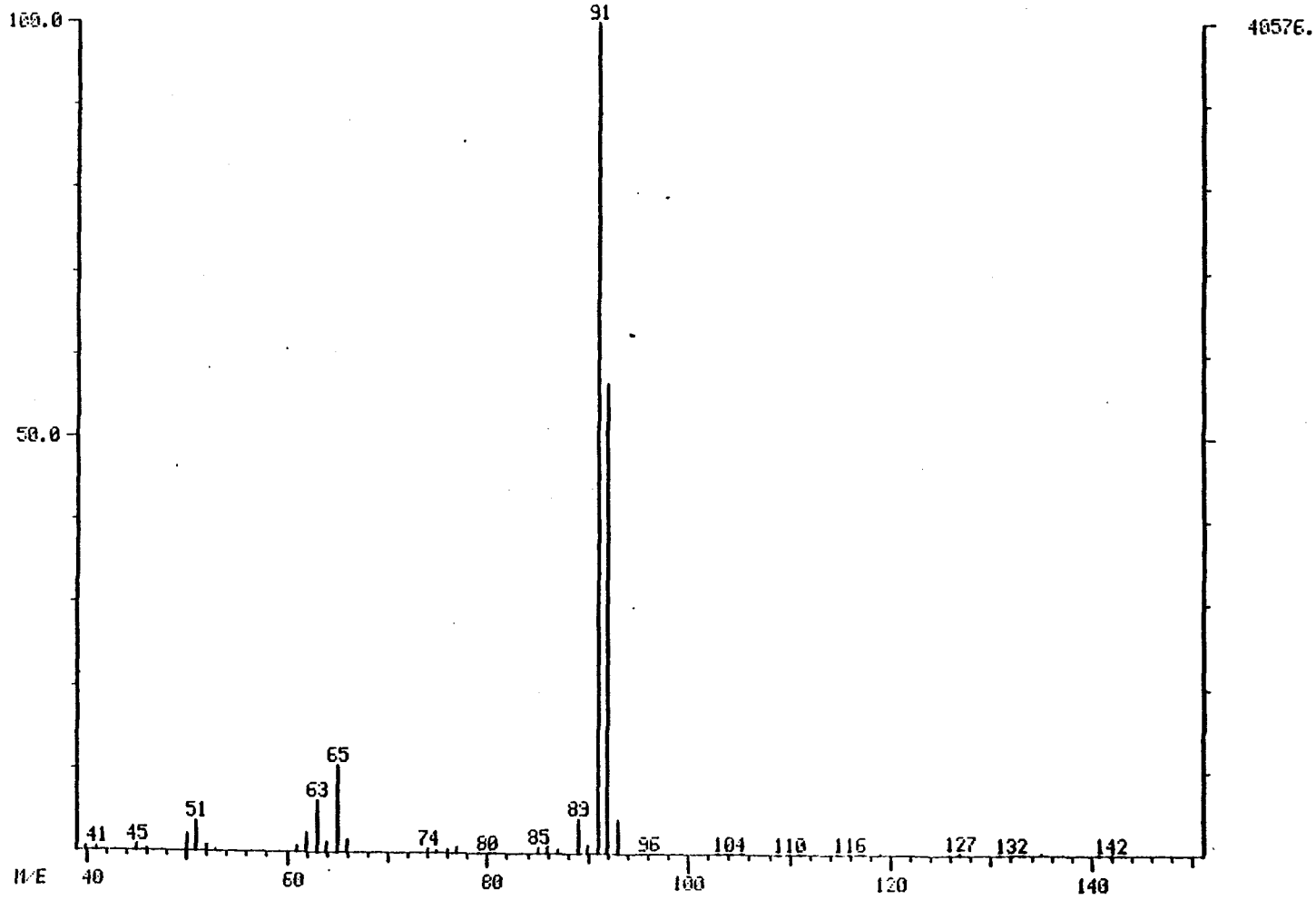
Carbon Tetrachloride



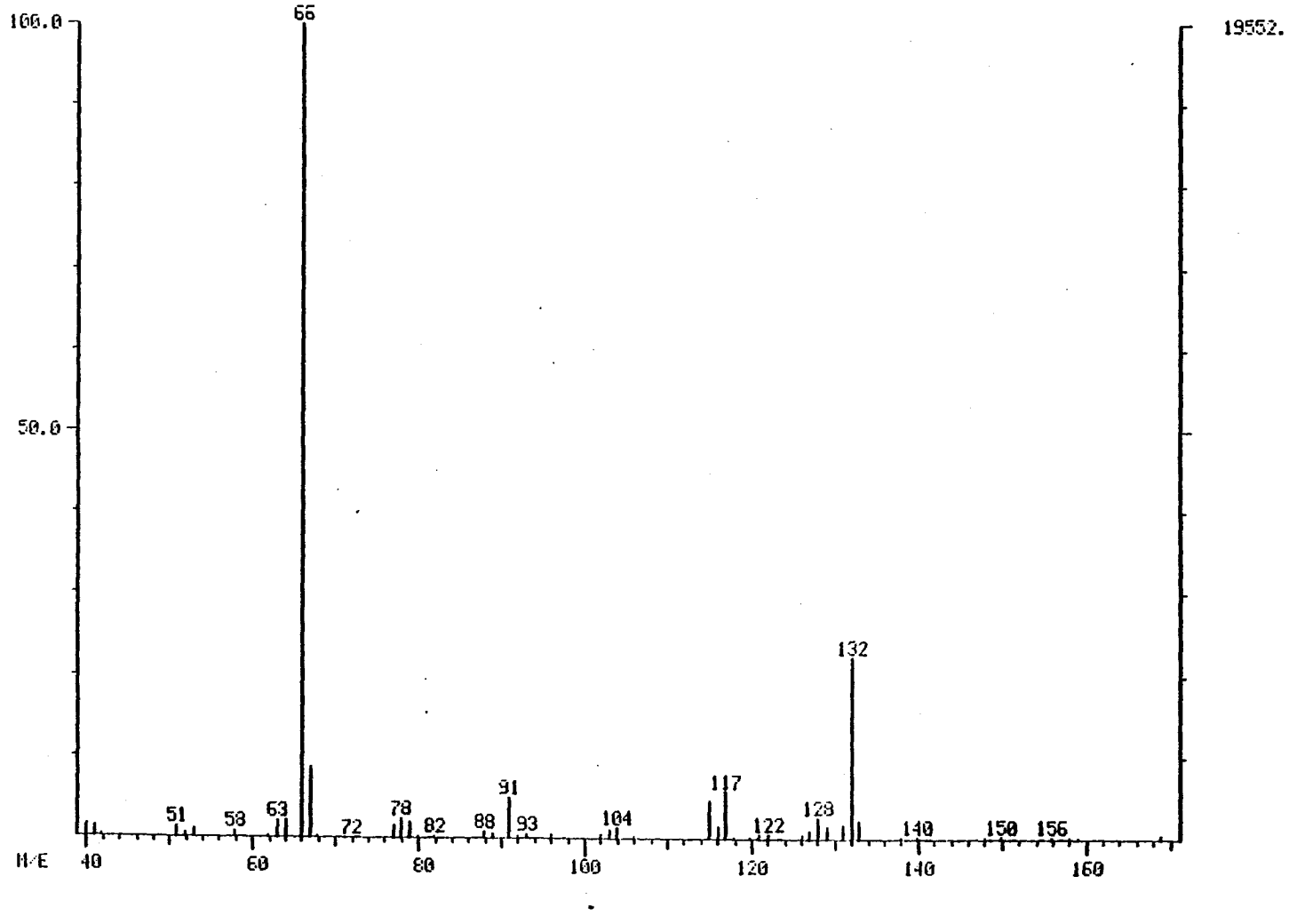

Bicycloheptadiene
32480.
100.0
50.0
M/E
91
66
63
51
43
56
74
82
86
97
102
108
113
125
132
145
40
60
80
100
120
140


Benzene
100.0
50.0
29632.
78
51
74
63
45
66
88
91
94
98
104
113
119
M/E
40
50
60
70
80
90
100
110
120

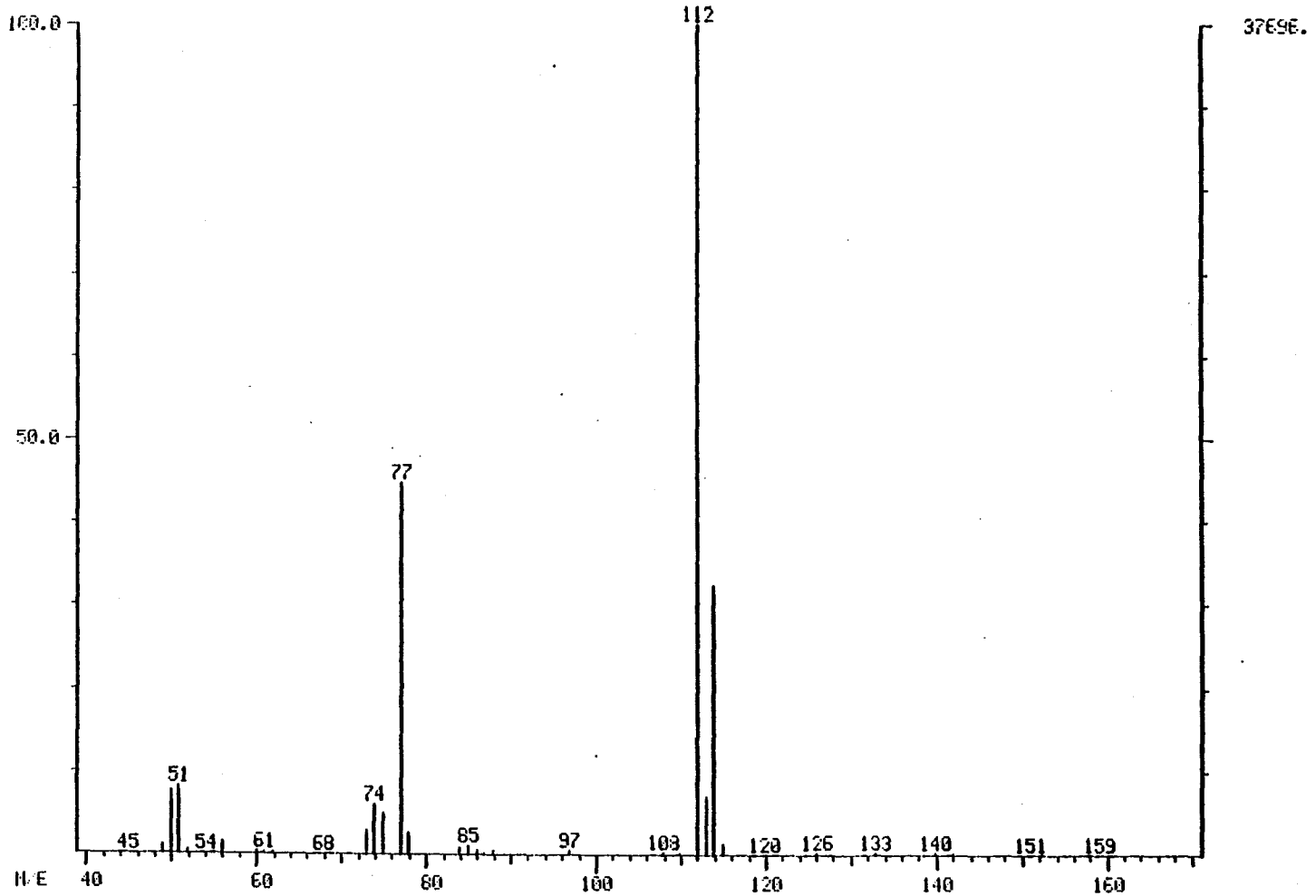
Toluene


100.0
50.0
91
40576.
65
63
51
89
41
45
74
80
85
96
104
110
116
127
132
142
M/E
40
60
80
100
120
140

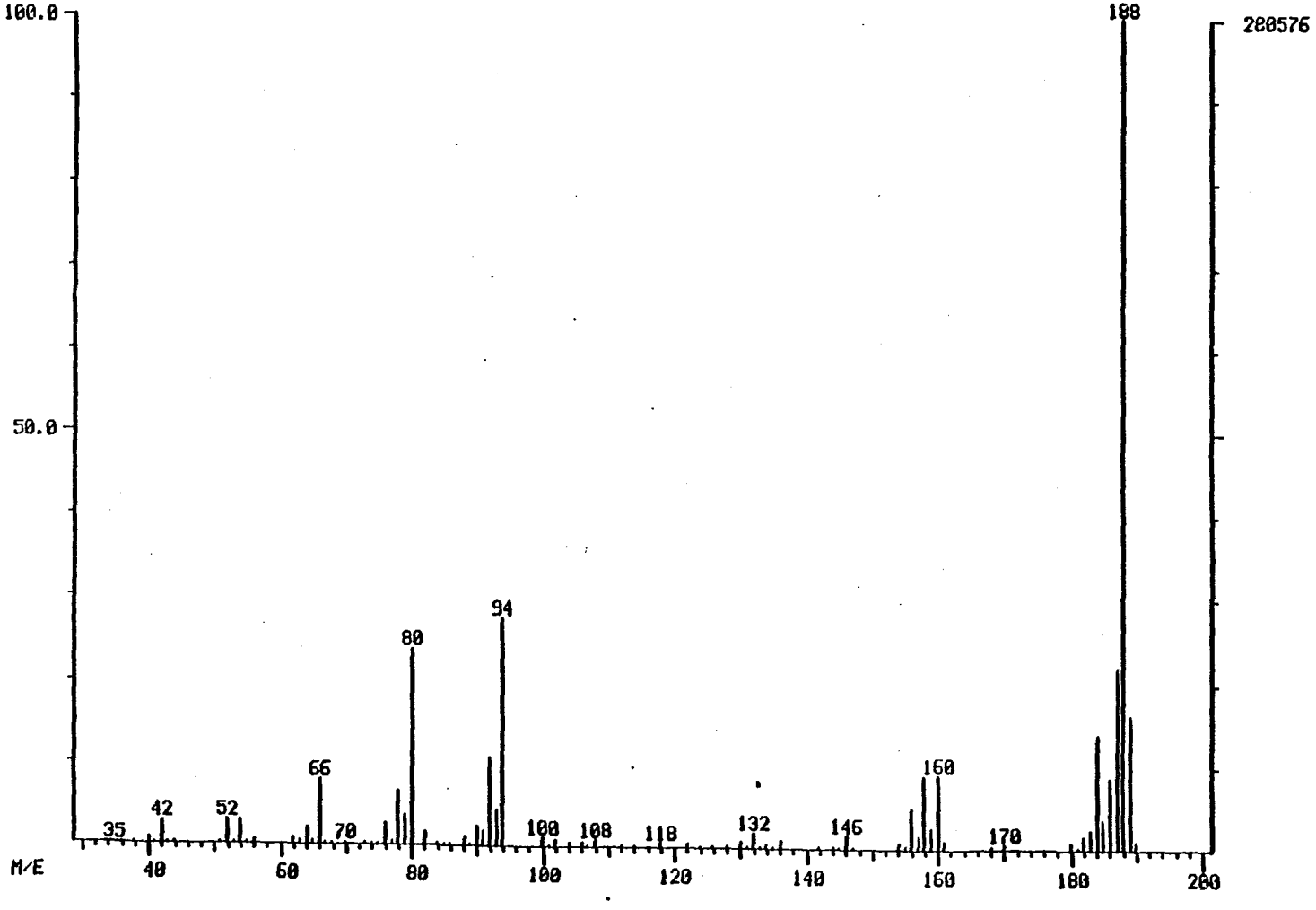
Dicyclopentadiene

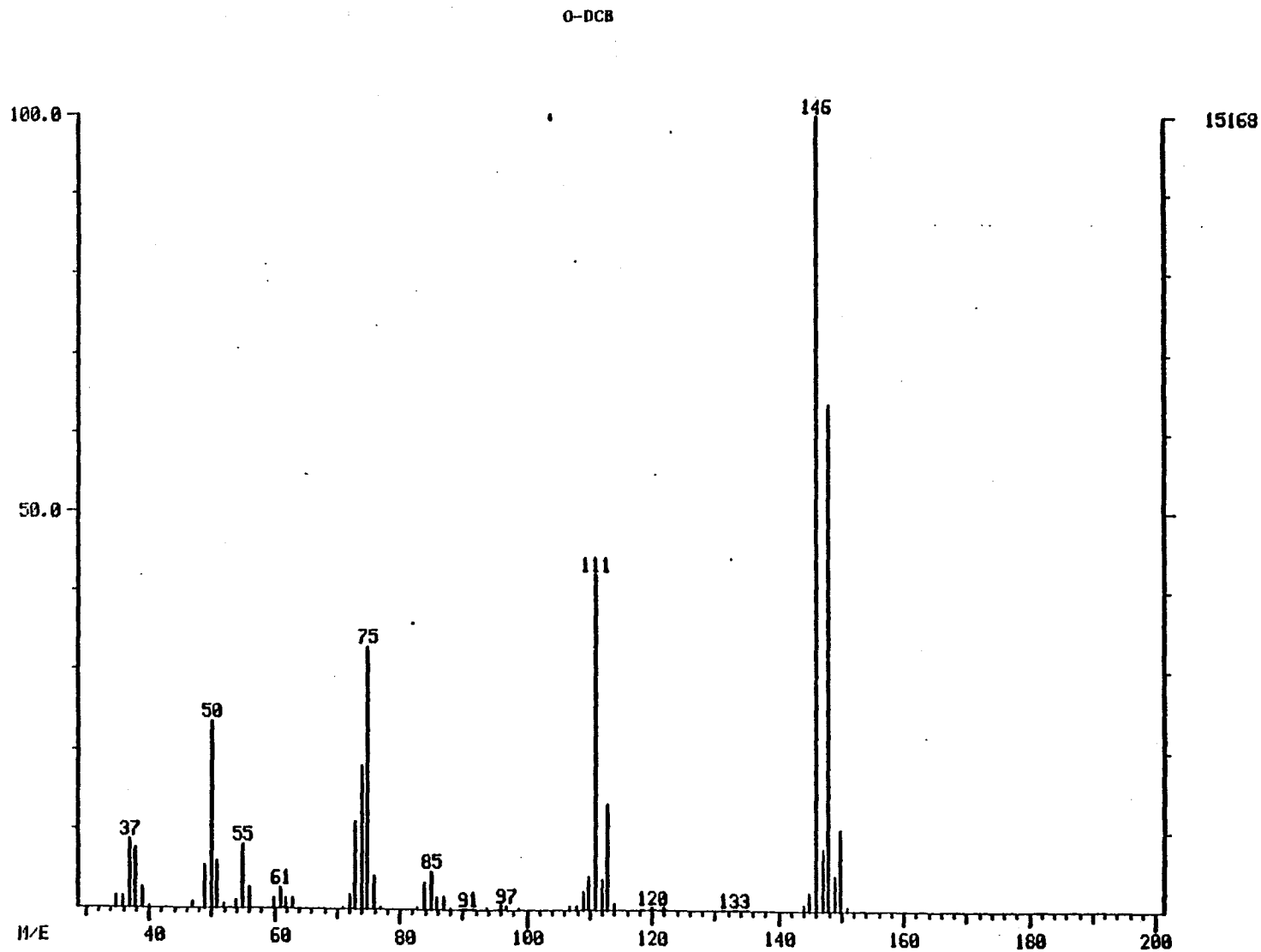


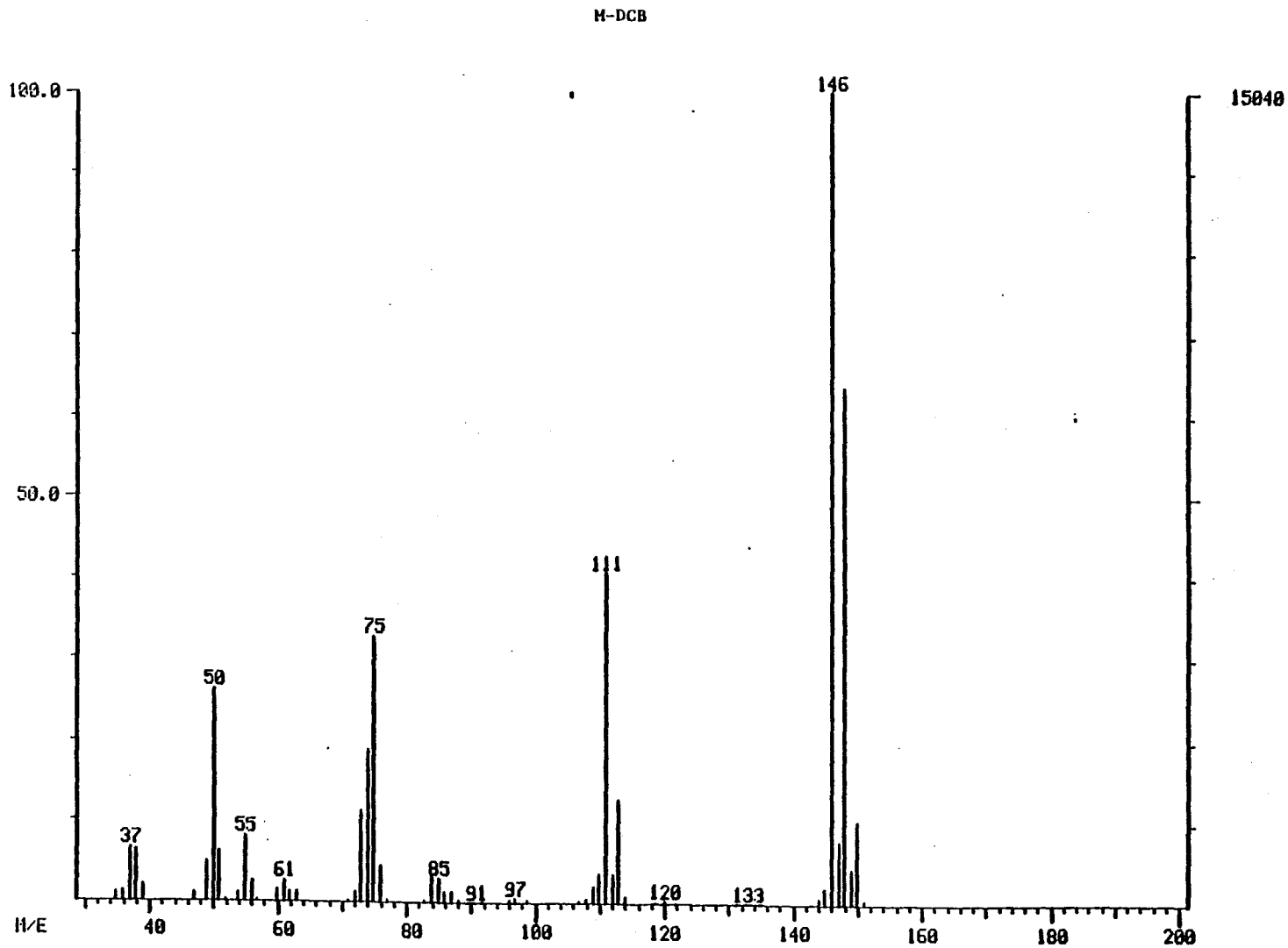
Chlorobenzene

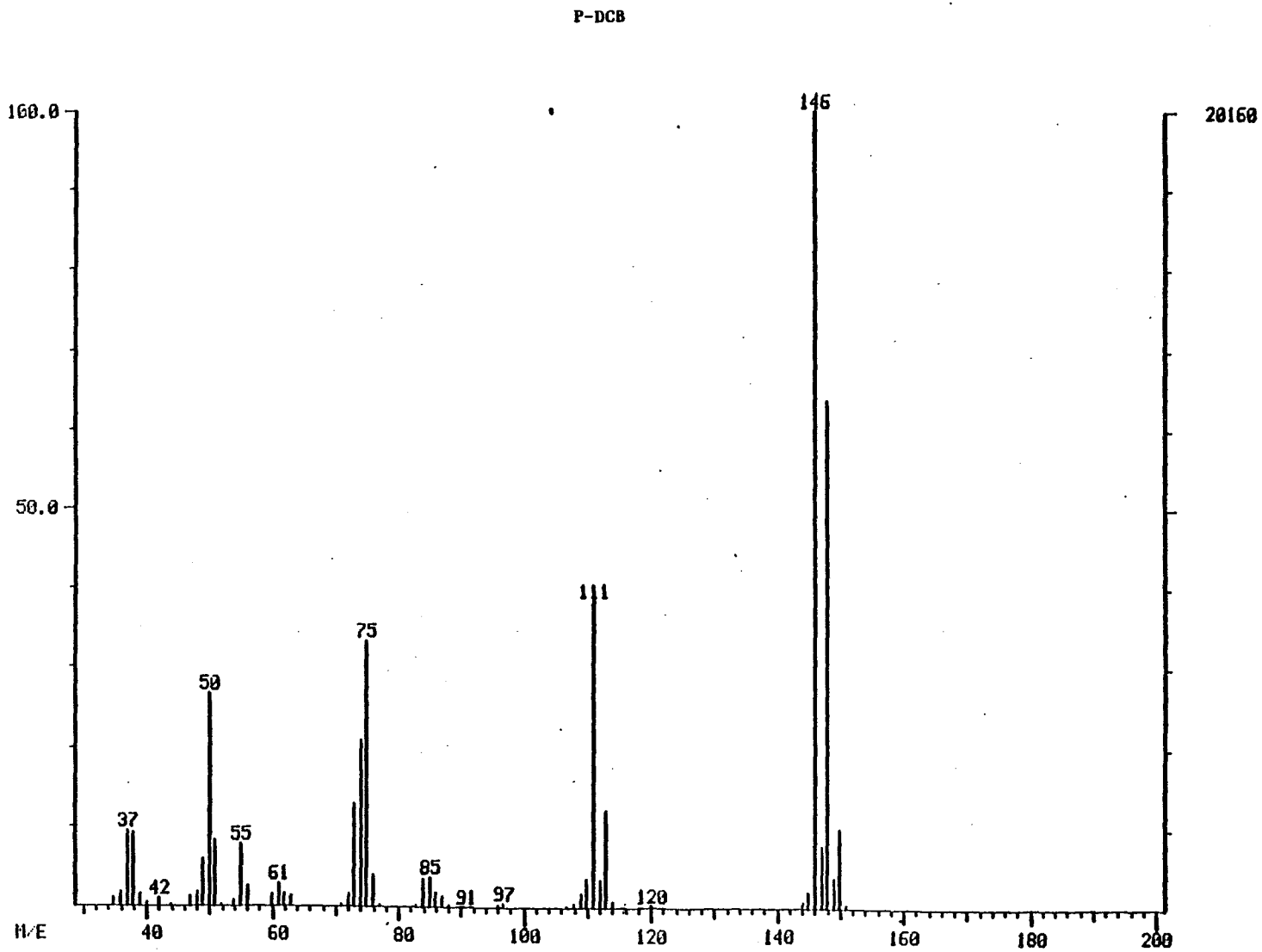


Dio-Anthracene

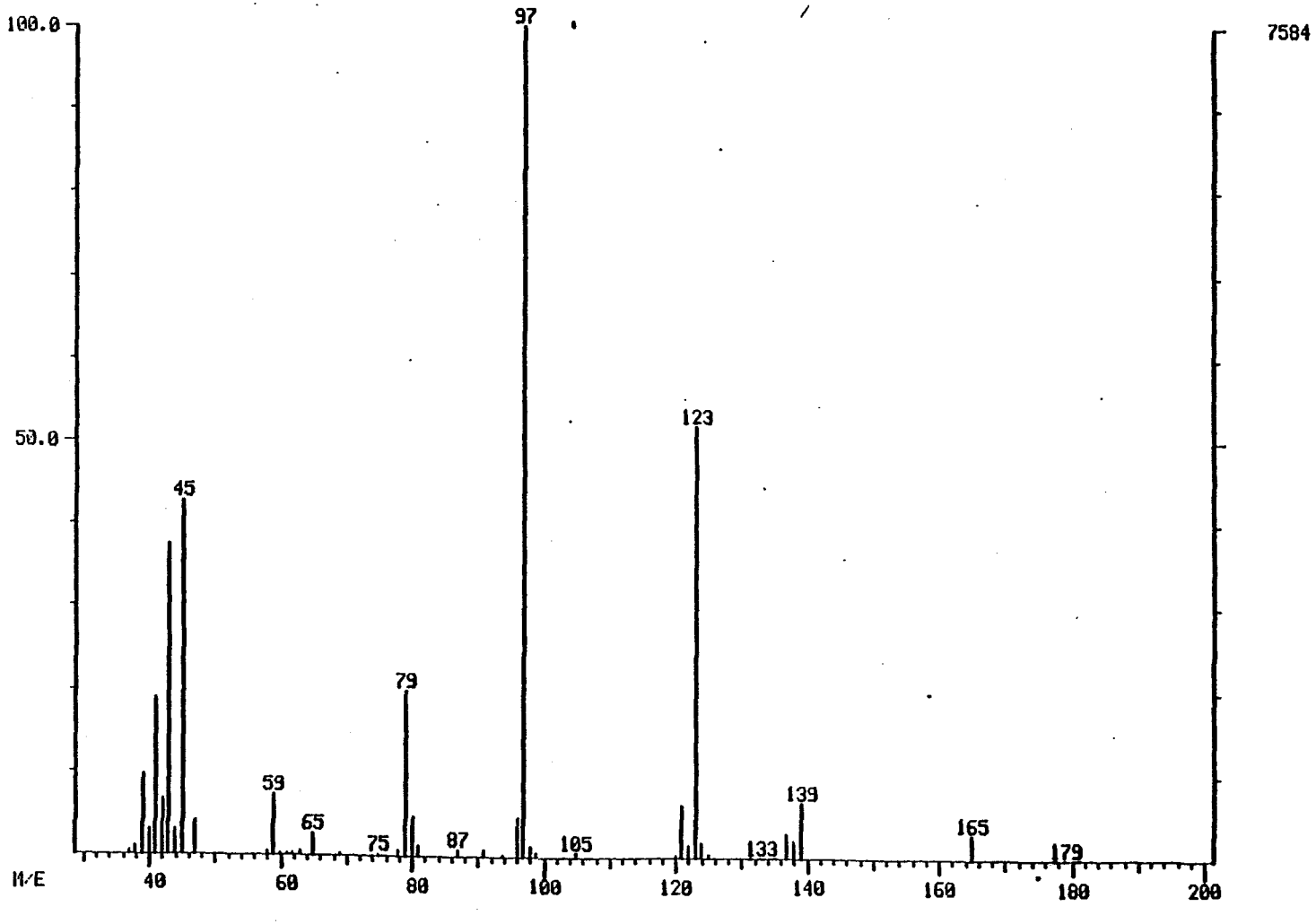



O-DCB
100.0
50.0
M/E
146
15168
111
75
50
37
55
61
85
91
97
120
133
40
60
80
100
120
140
160
180
200

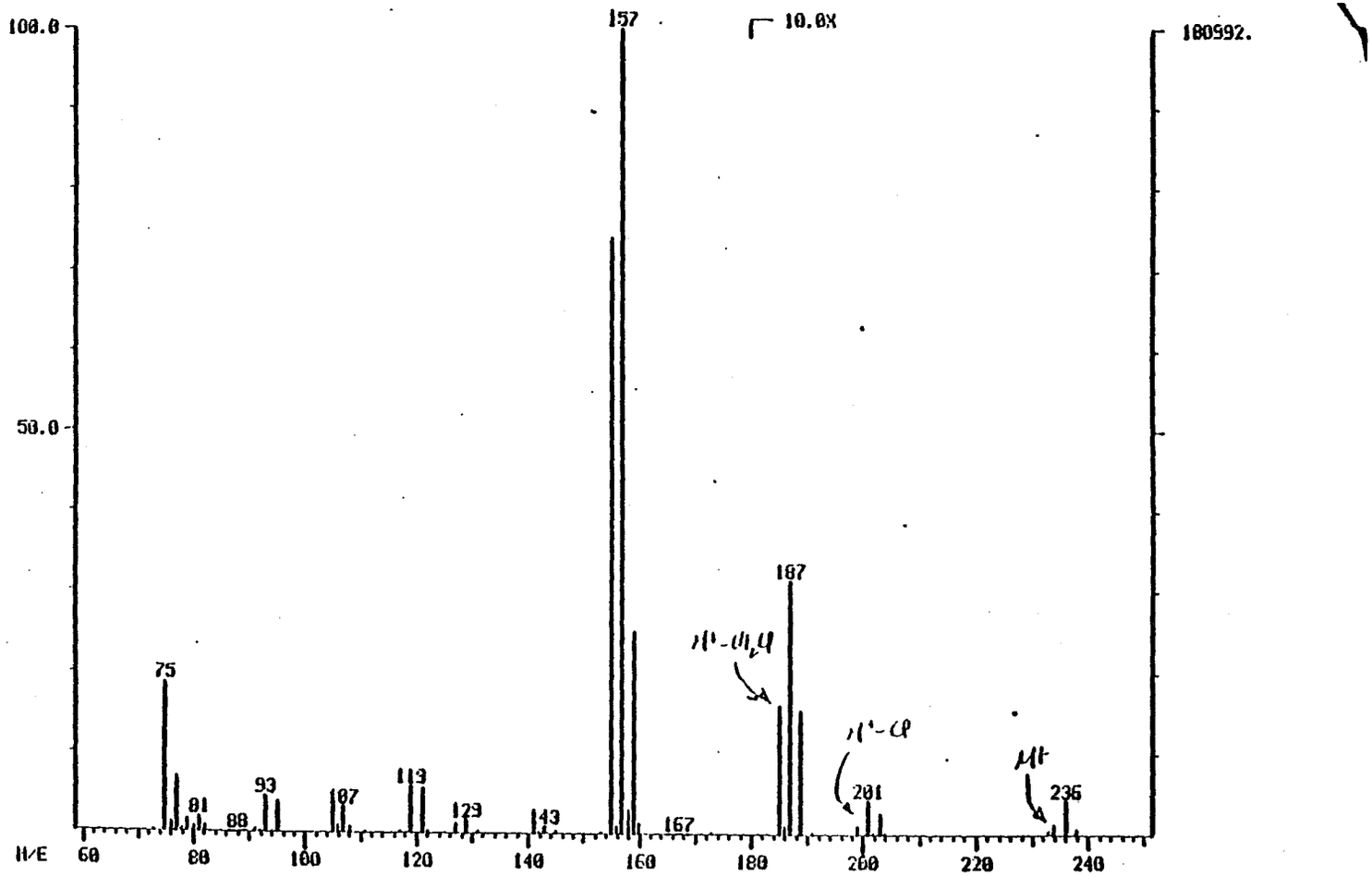

M-DCB
100.0
50.0
15040
146
111
75
50
37
55
61
85
91
97
120
133
M/E
40
60
80
100
120
140
160
180
200


P-DCB
100.0
50.0
M/E
146
20160
111
75
50
37
55
61
85
91
97
120
40
60
80
100
120
140
160
180
200

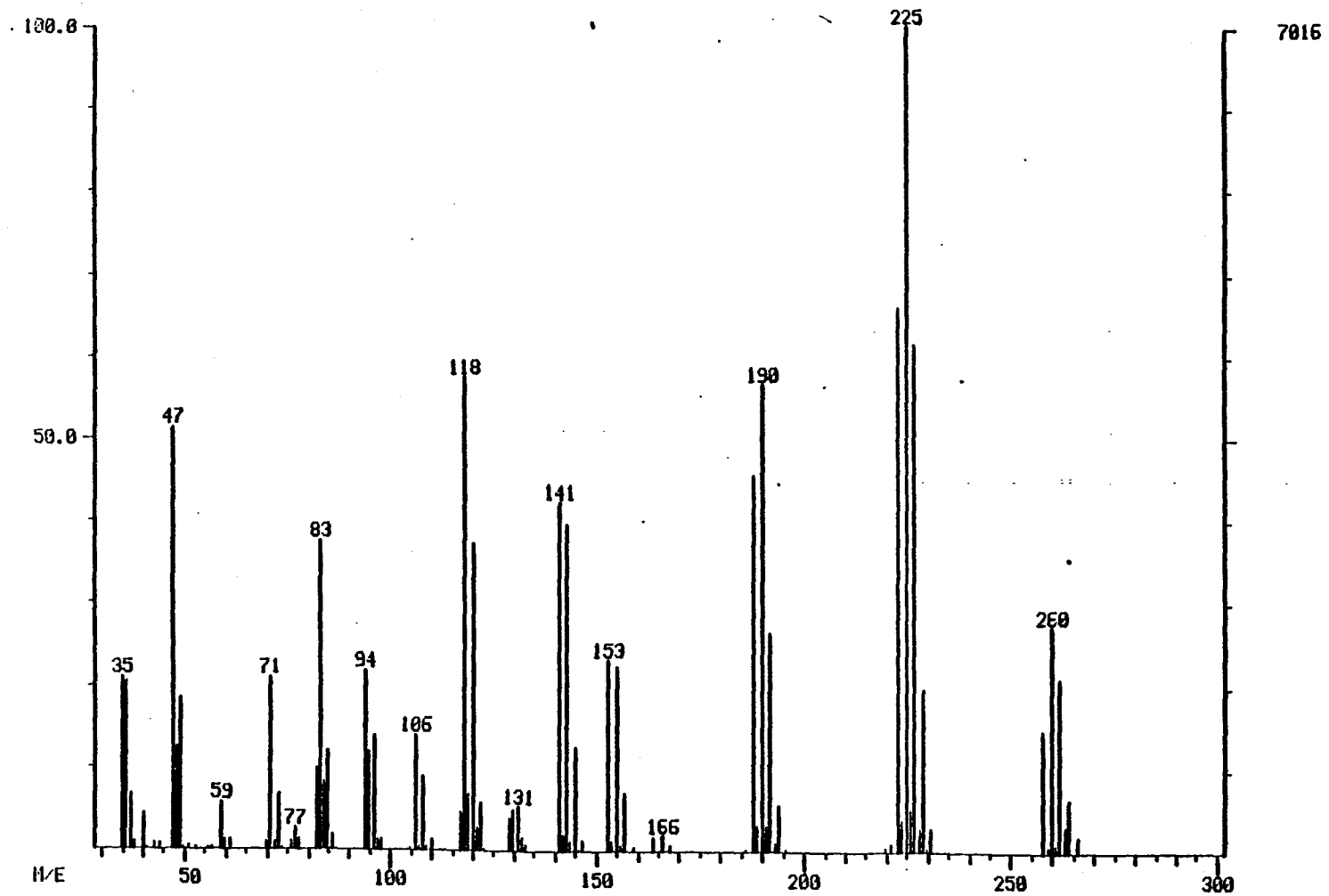
DIMP


100.0
50.0
M/E
97
7584
123
45
79
59
65
75
87
105
133
139
165
179
40
60
80
100
120
140
160
180
200

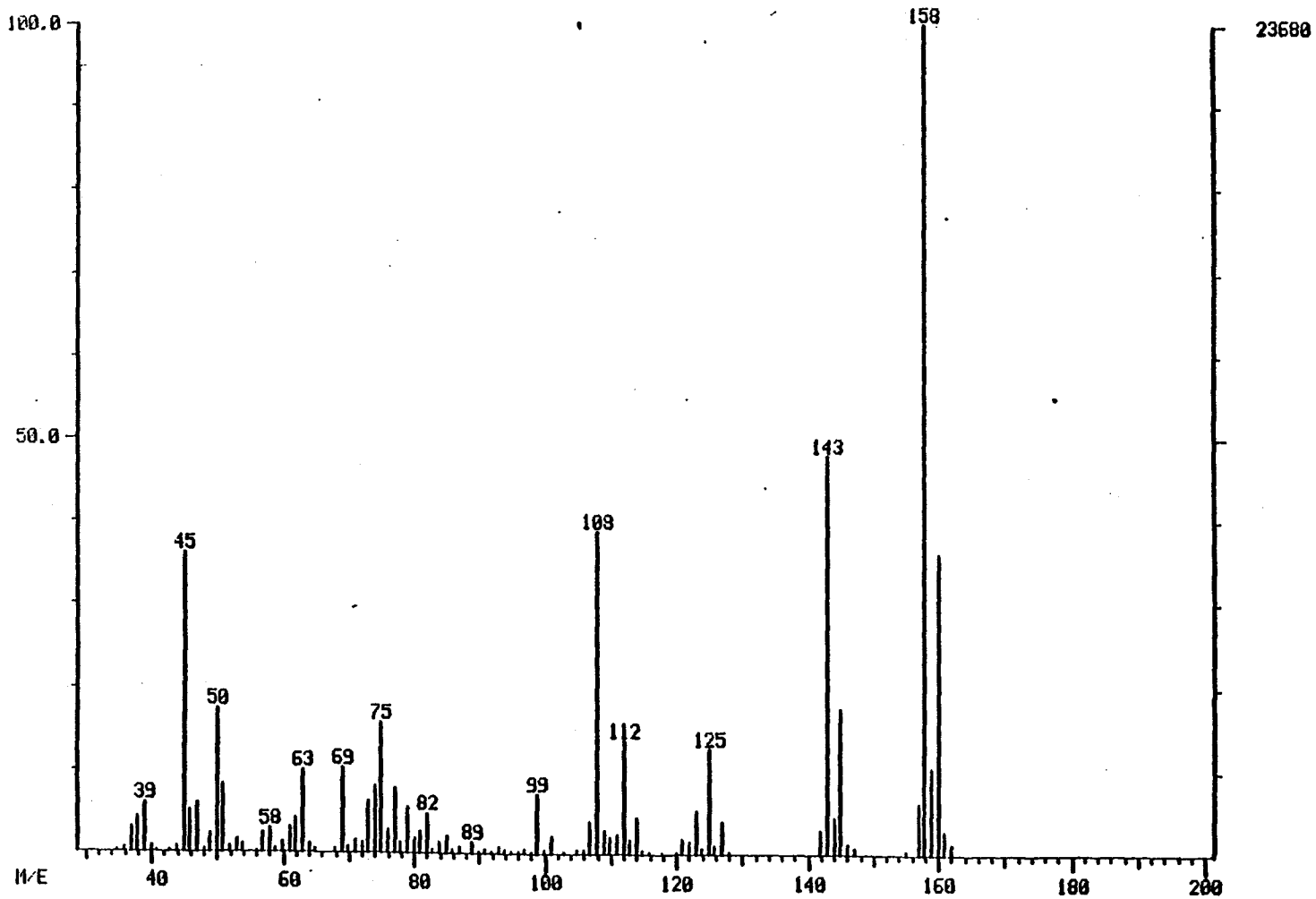
DBCP

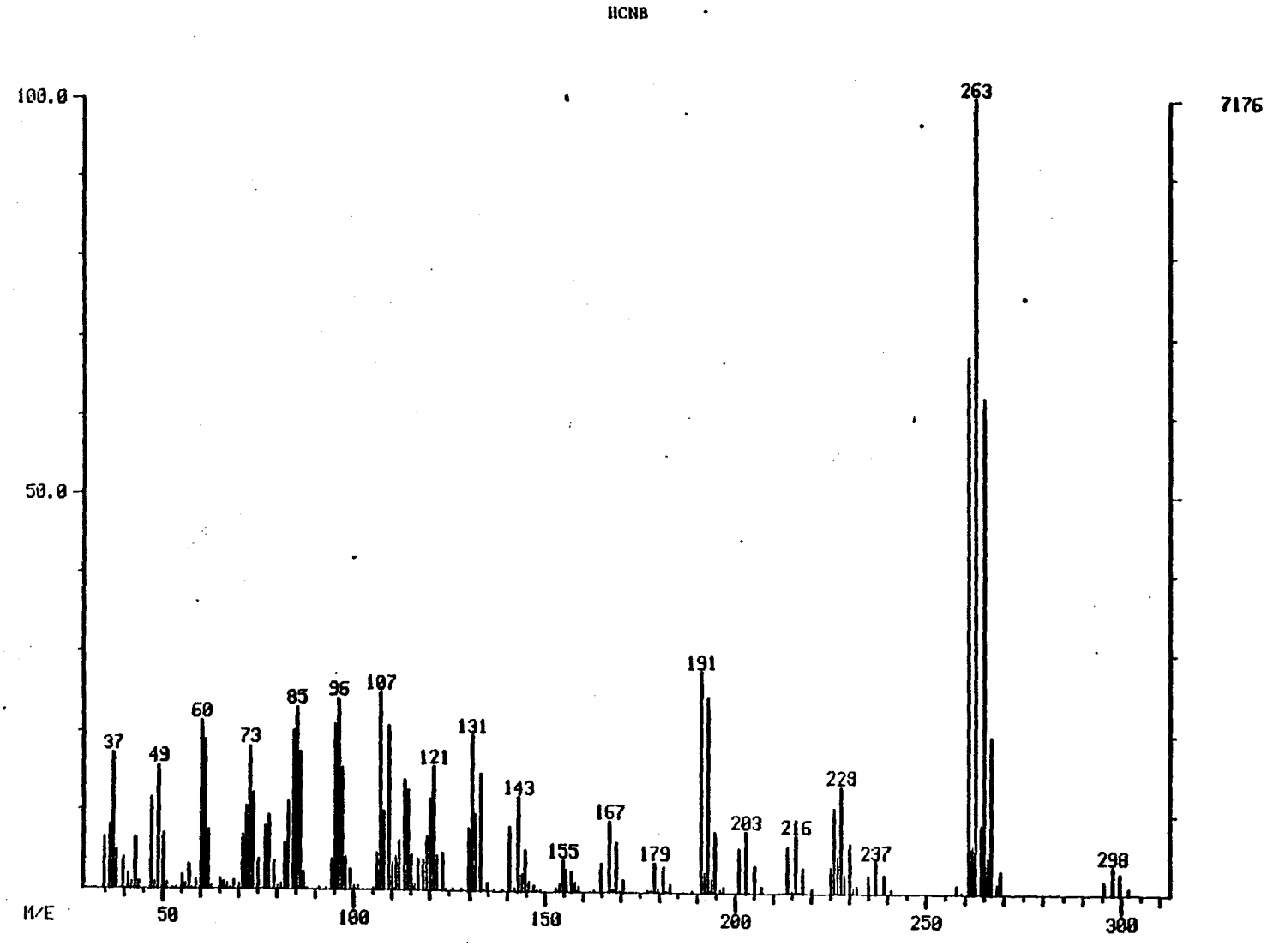

100.0
50.0
157
10.0X
180992.
187
M+-Cl2
M+-Cl
M+
75
81
88
93
107
113
123
143
167
201
236
M/E
60
80
100
120
140
160
180
200
220
240

HCBD

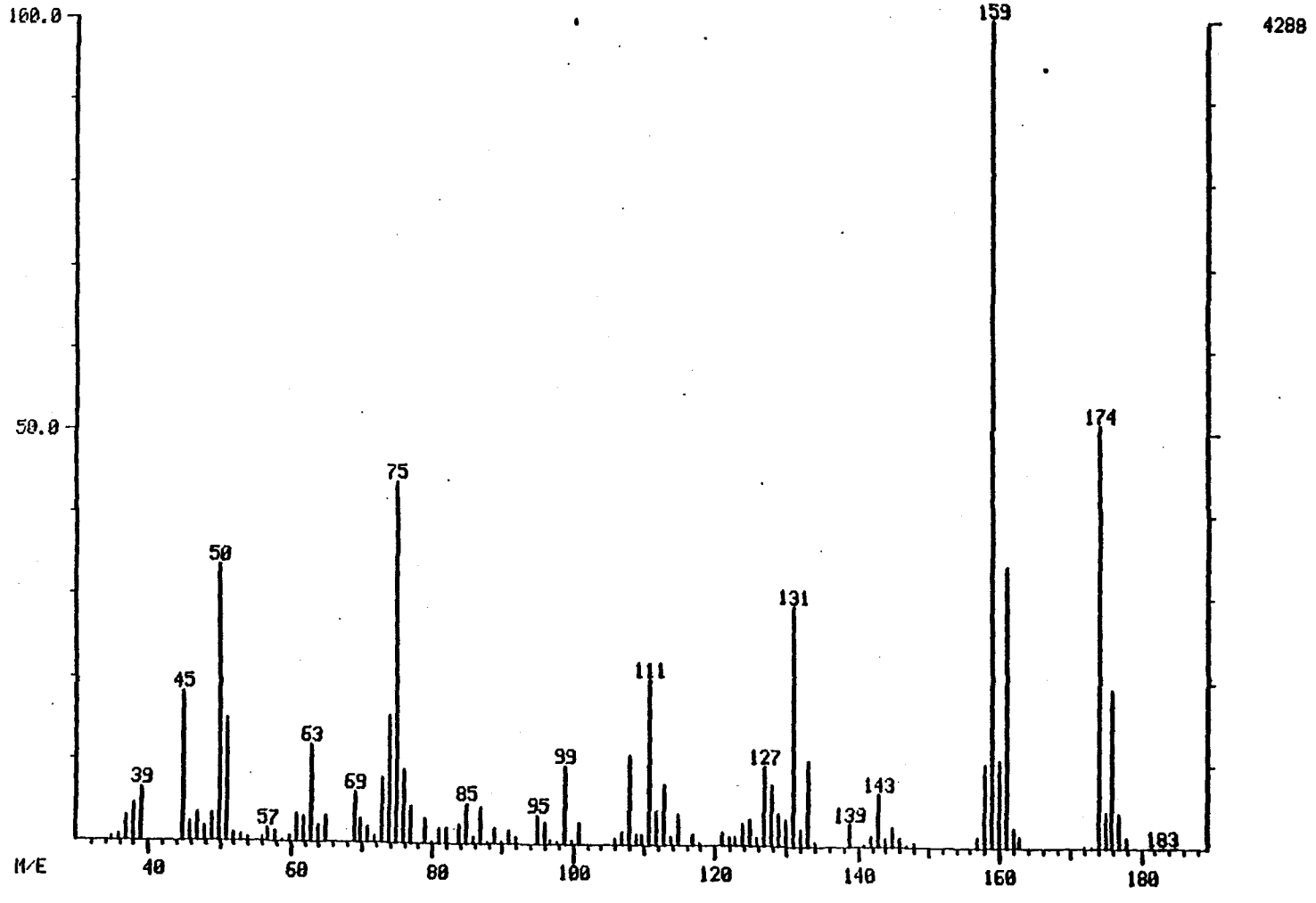

100.0
50.0
M/E
7016
225
190
118
141
47
83
260
153
35
71
94
106
59
77
131
166
50
100
150
200
250
300

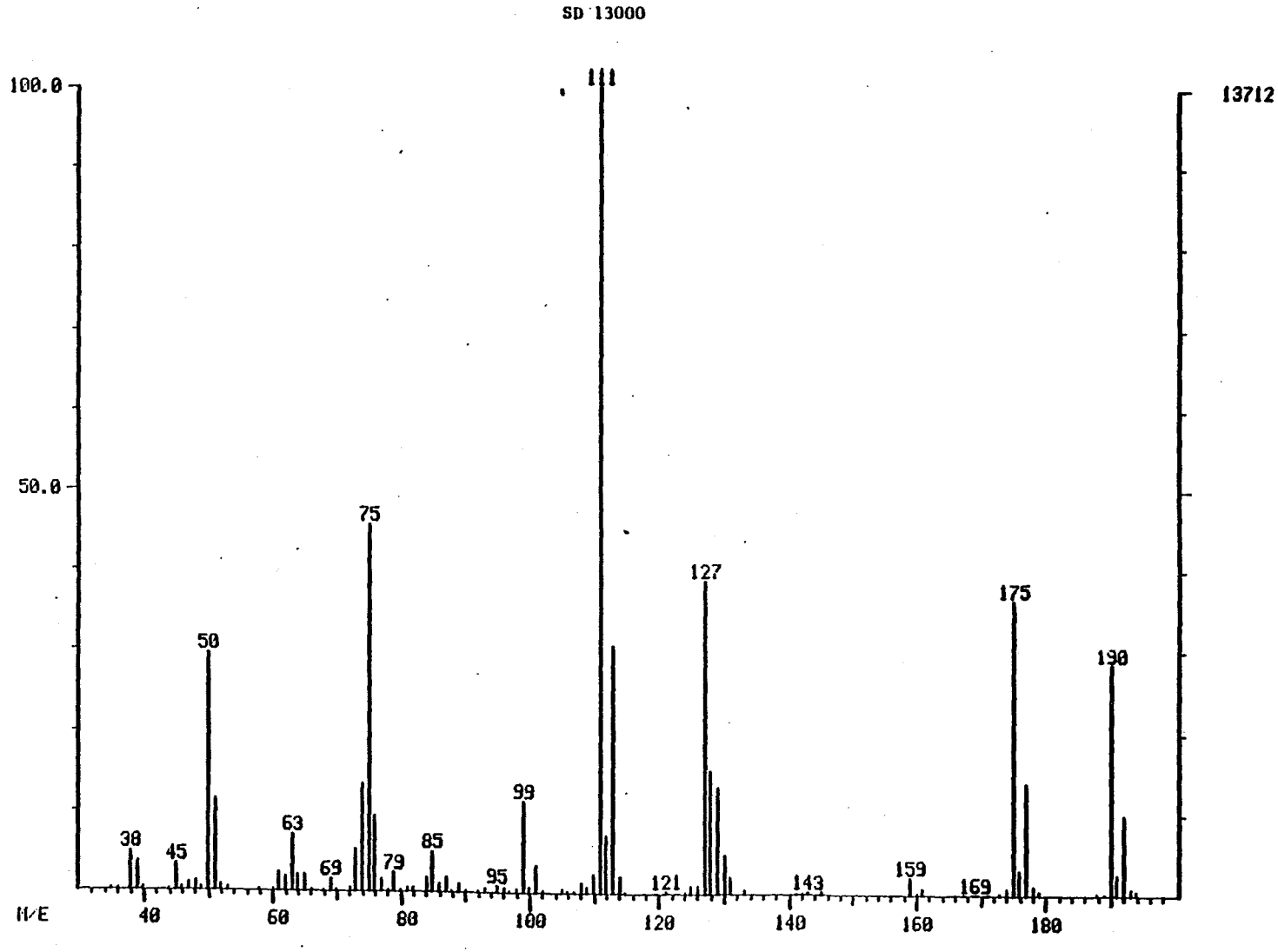
SD 9636


100.0
50.0
M/E
23680
158
143
109
45
50
75
112
125
63
69
39
58
82
89
99
40
60
80
100
120
140
160
180
200

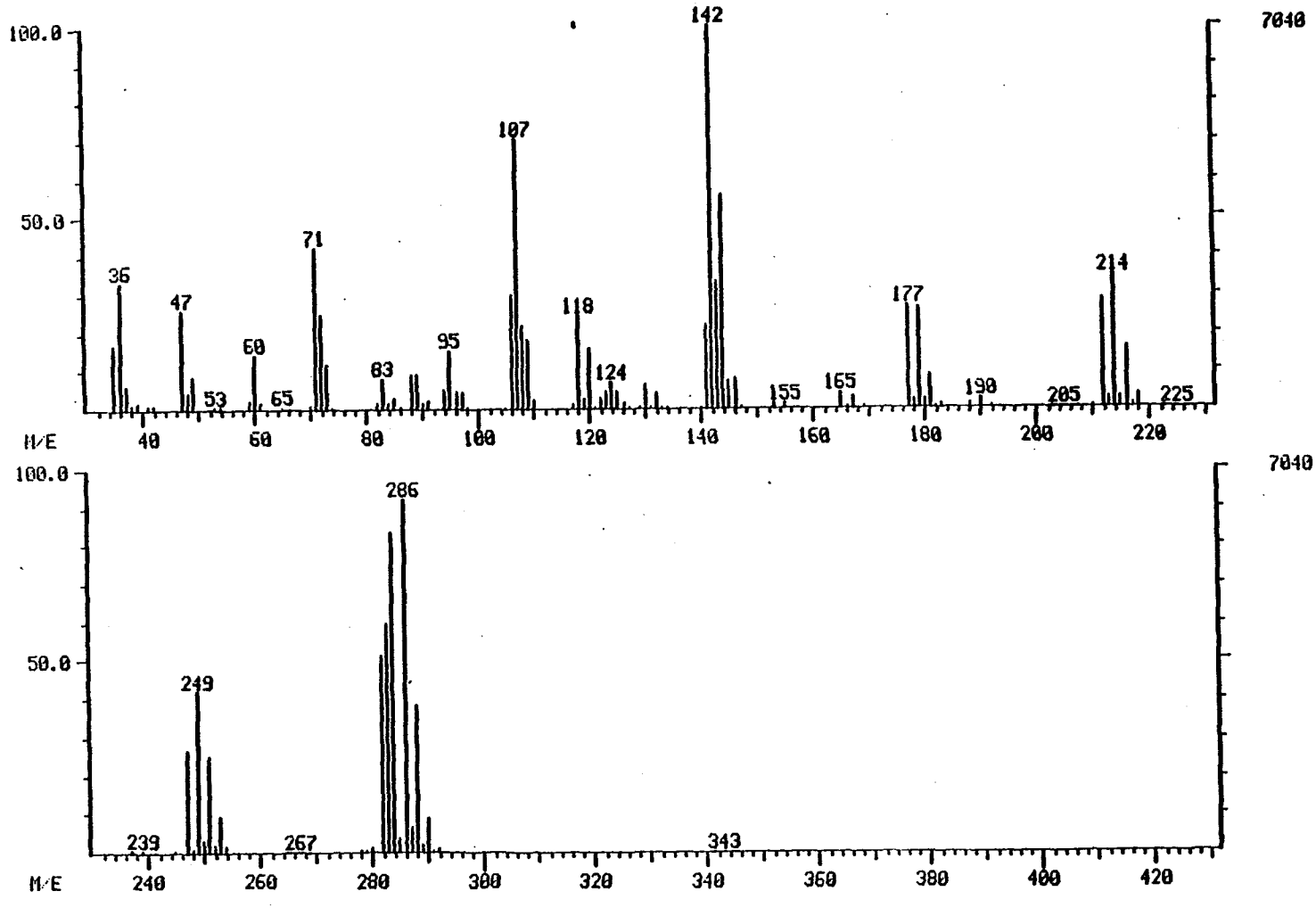

HCNB
100.0
50.0
7176
M/E
50
100
150
200
250
300
263
191
107
96
85
60
73
37
49
121
131
143
155
167
179
203
216
228
237
298

SD 13957

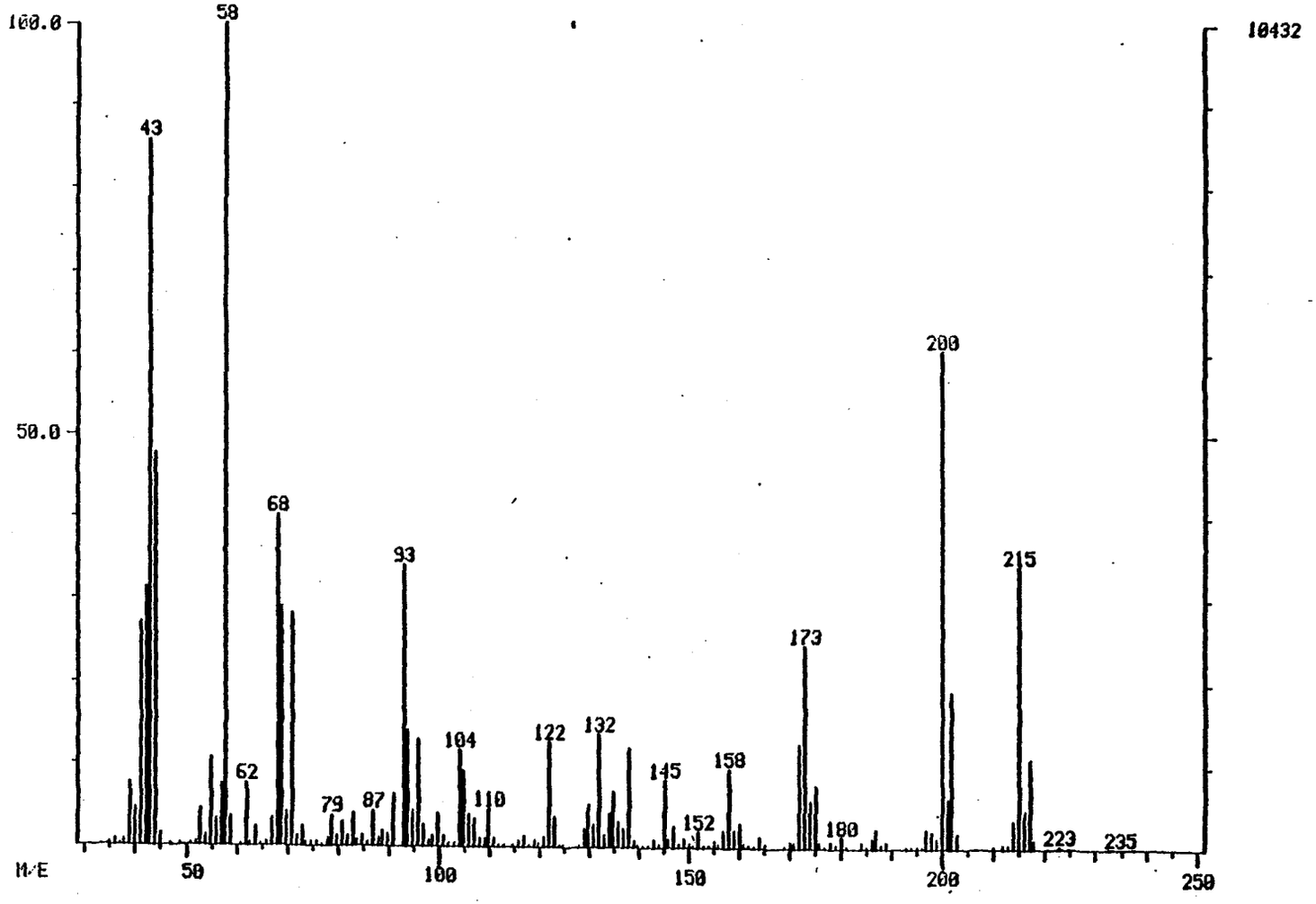

100.0
50.0
M/E
4288
159
174
131
111
75
50
45
63
39
69
57
85
95
99
127
139
143
183
40
60
80
100
120
140
160
180


SD 13000
100.0
50.0
13712
111
75
50
127
175
190
99
63
38
45
69
79
85
95
121
143
159
169
M/E
40
60
80
100
120
140
160
180

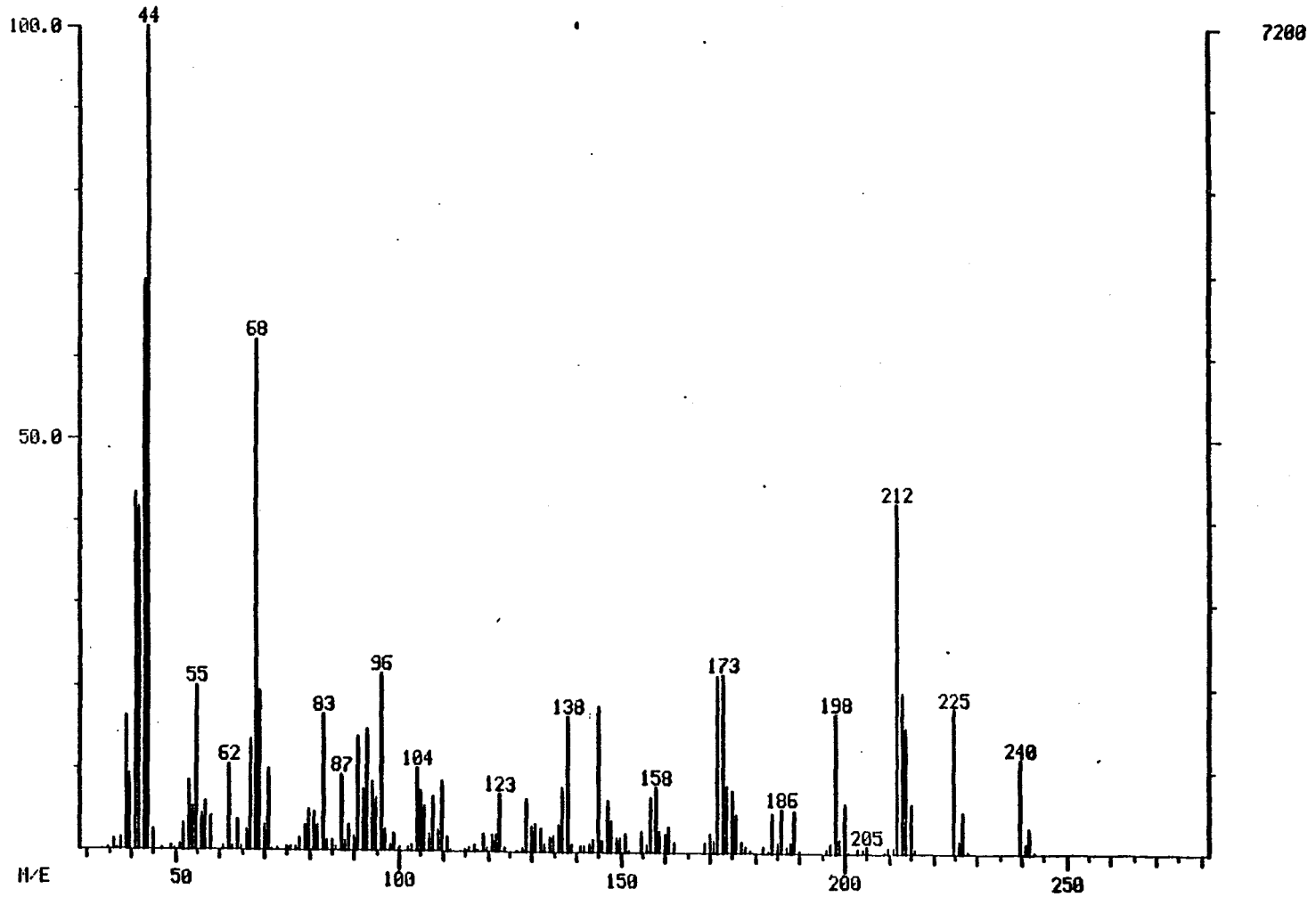
HCB

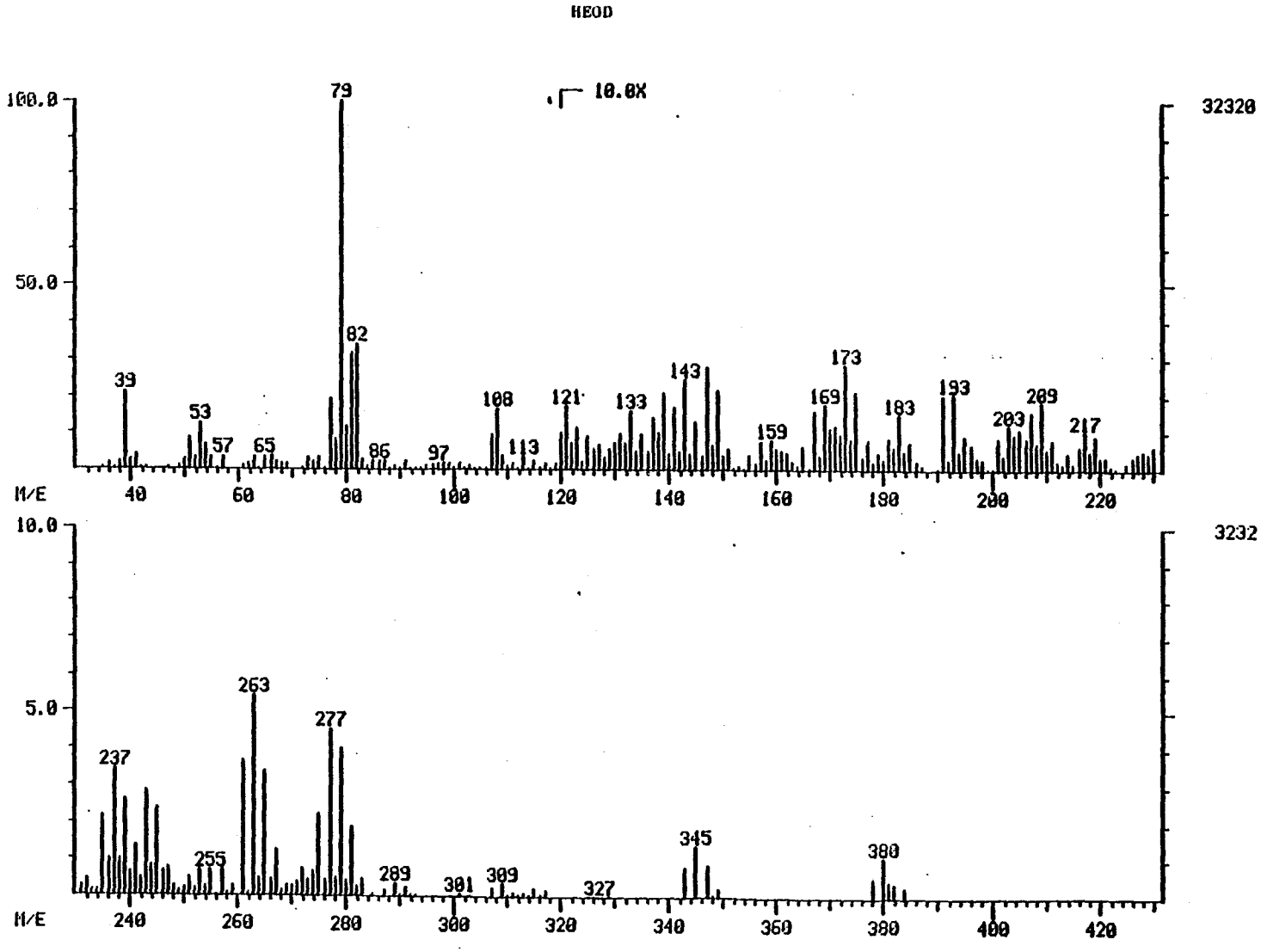

100.0
50.0
7040
142
107
71
36
47
60
95
83
118
124
214
177
53
65
155
165
190
205
225
M/E
40
60
80
100
120
140
160
180
200
220
100.0
50.0
7040
286
249
239
267
343
M/E
240
260
280
300
320
340
360
380
400
420

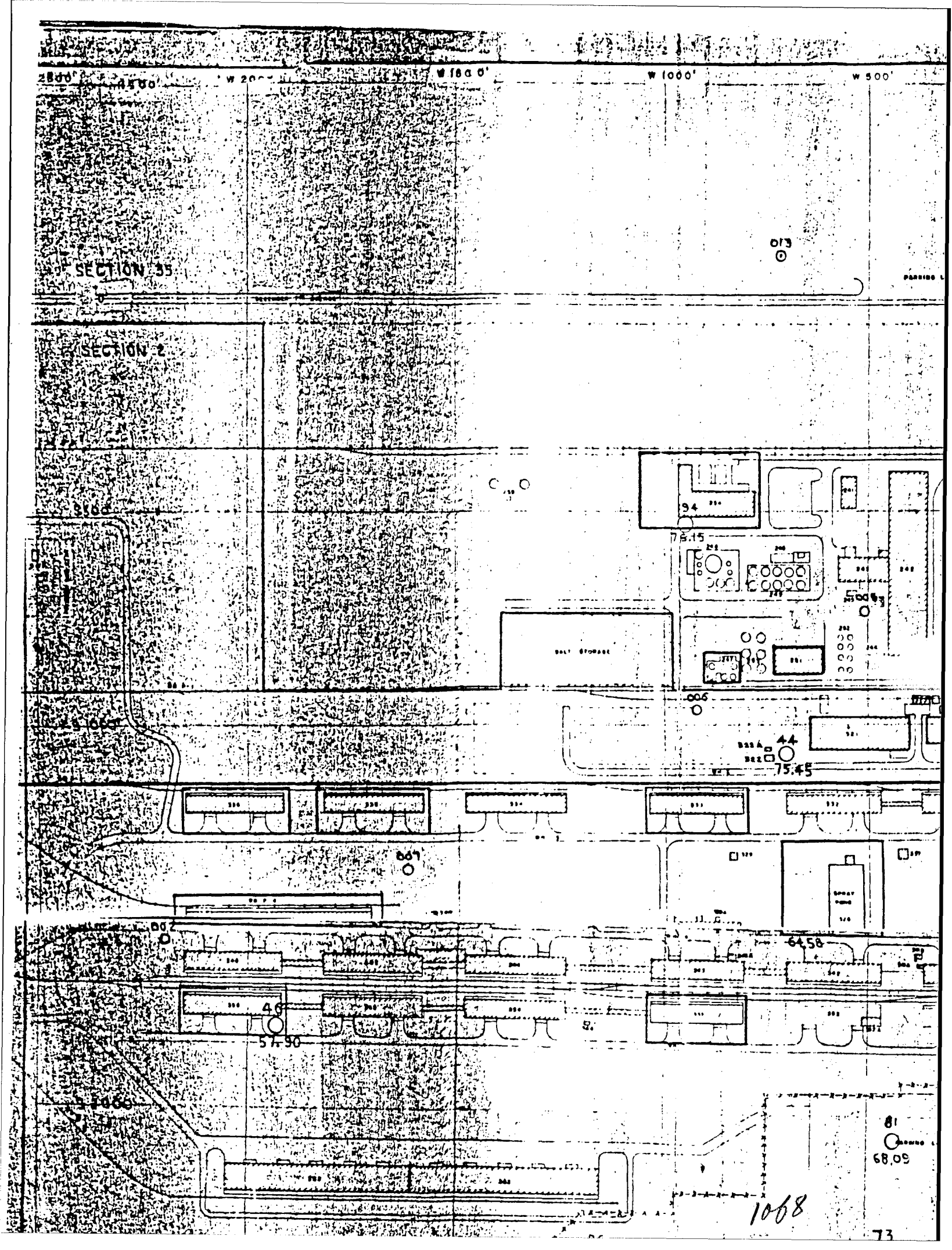
Atrazine

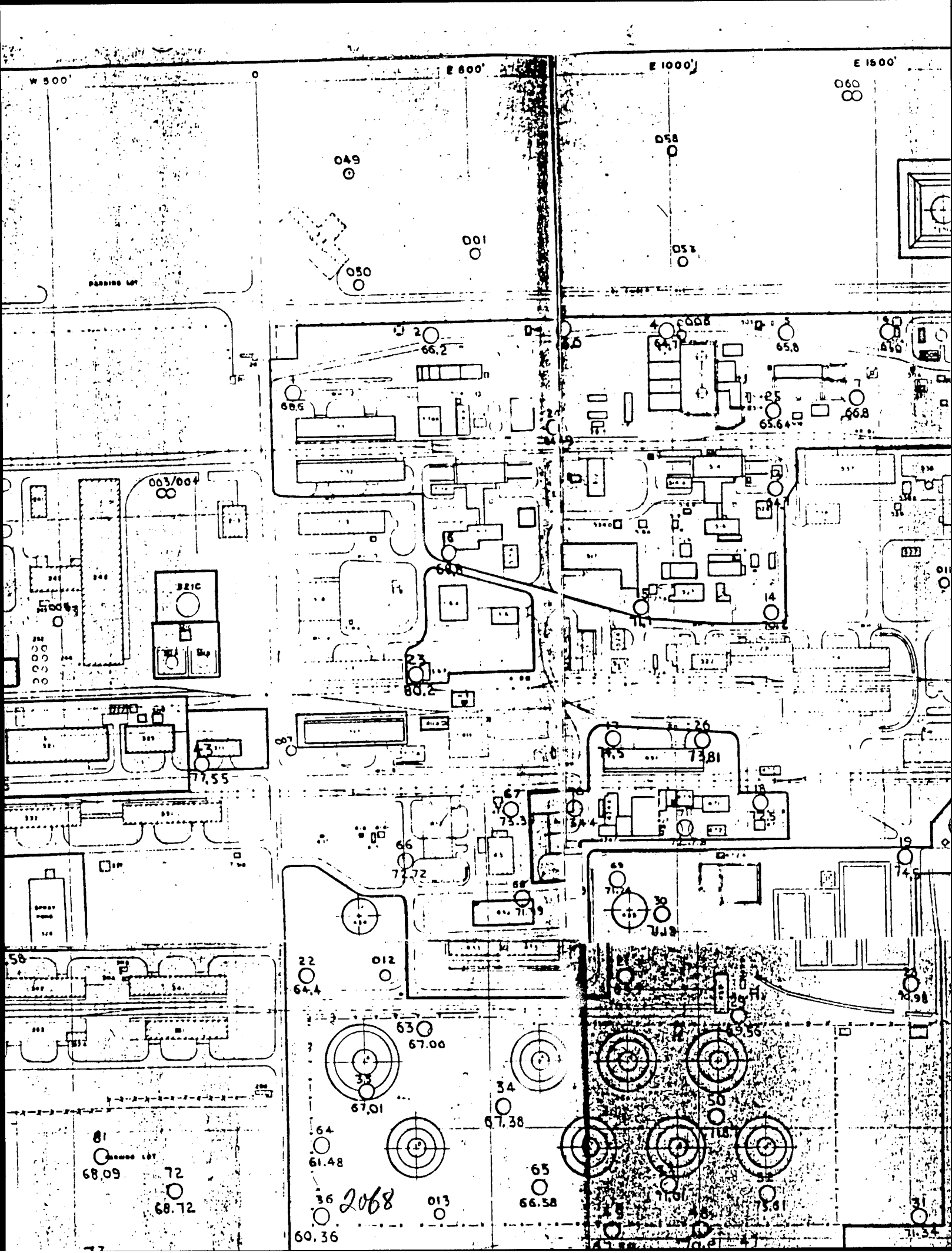

100.0
50.0
M/E
10432
58
43
68
93
62
79
87
104
110
122
132
145
152
158
173
180
200
215
223
235
50
100
150
200
250

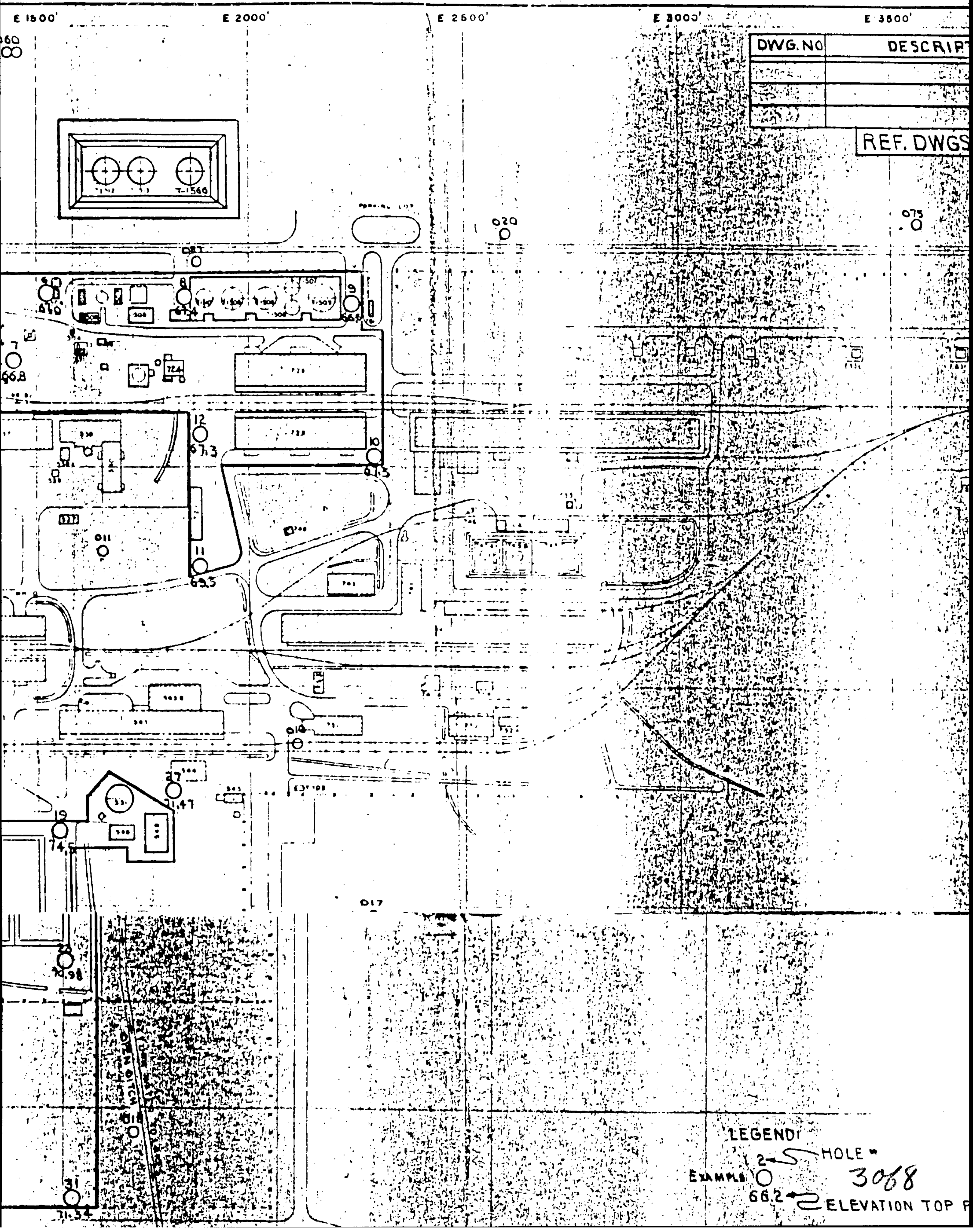
BLADEX


100.0
50.0
7200
44
68
55
62
83
87
96
104
123
138
158
173
186
198
205
212
225
240
M/E
50
100
150
200
250

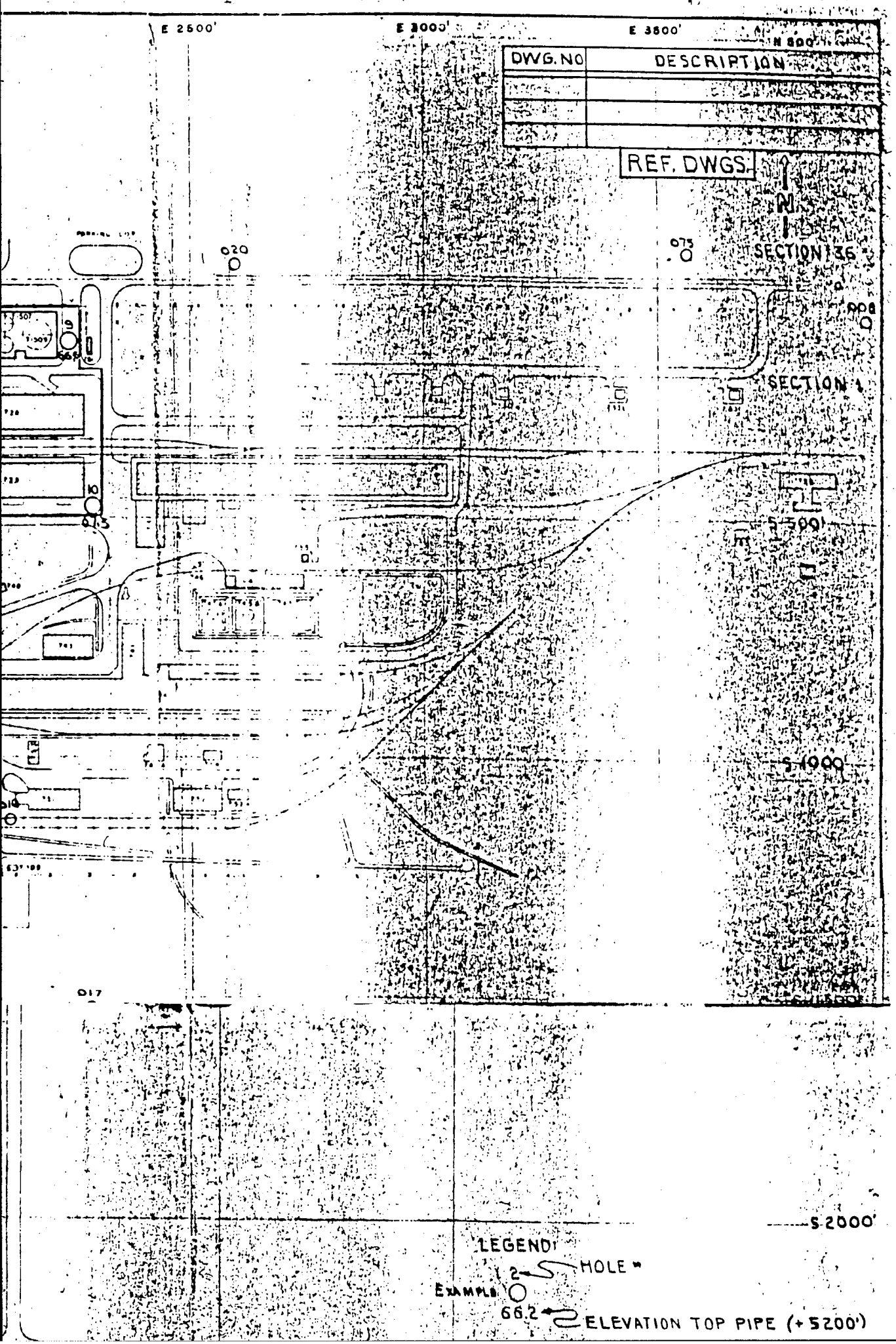

HEOD
10.0X
100.0
50.0
32320
79
82
39
53
57
65
86
97
108
113
121
133
143
159
169
173
183
193
203
209
217
M/E
40
60
80
100
120
140
160
180
200
220
10.0
5.0
3232
263
277
237
255
289
301
309
327
345
380
M/E
240
260
280
300
320
340
360
380
400
420


2800'
W 1500'
W 1800'
W 1000'
W 500'
SECTION 35
SECTION 2
S 500'
S 1000'
S 1066'
013
94
78.15
006
44
75.45
007
64.58
46
57.90
81
68.09
1068
73

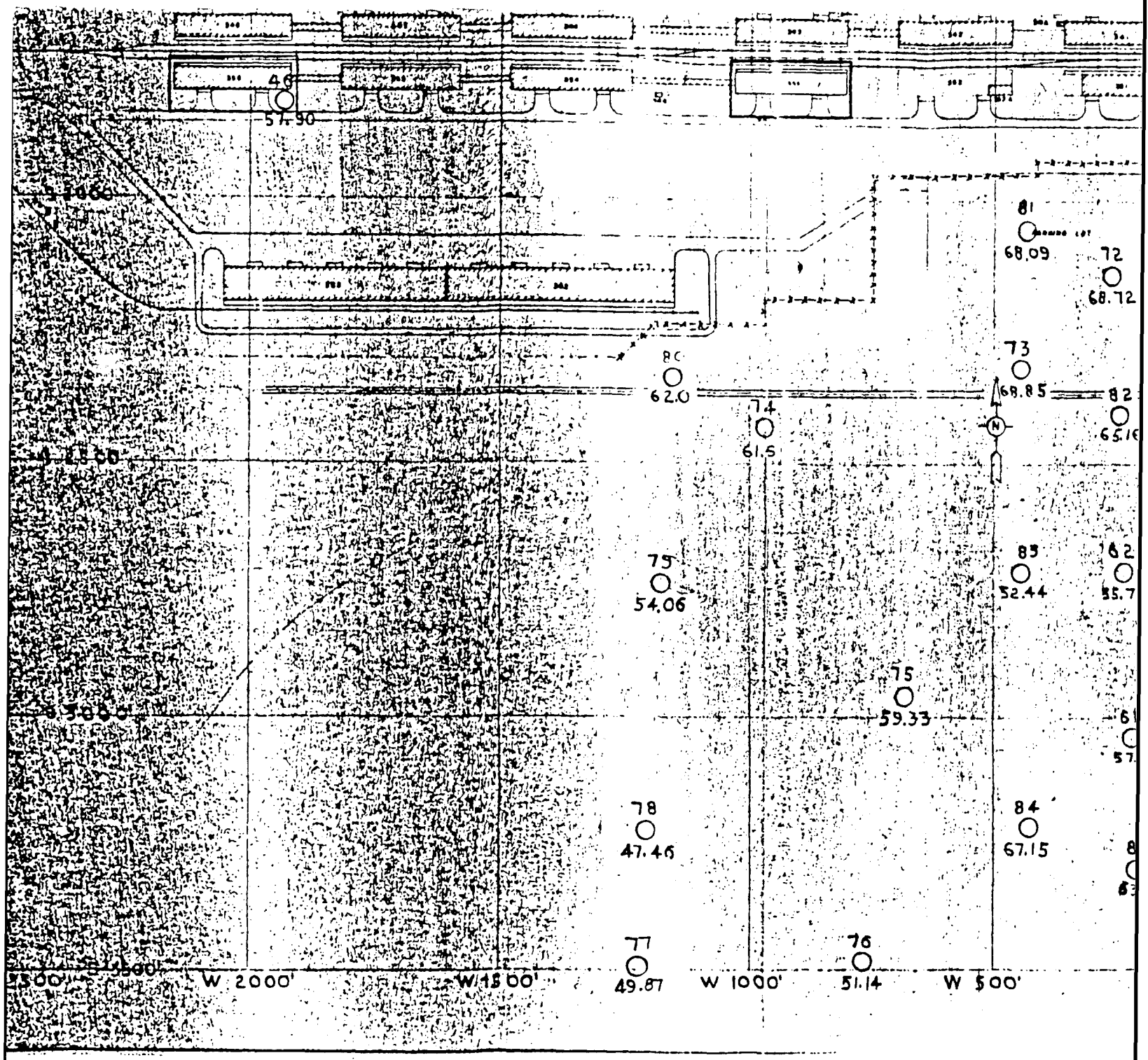

W 500'
E 800'
E 1000'
E 1500'
049
001
050
058
053
060
66.2
68.6
65.8
65.64
66.8
003/004
321C
68.2
77.55
73.81
75.3
72.72
74.6
22
64.4
012
63
67.00
67.01
34
67.38
64
61.48
65
66.58
36
60.36
013
2068
81
68.09
72
68.72
69.35
71.0
75.61
71.34



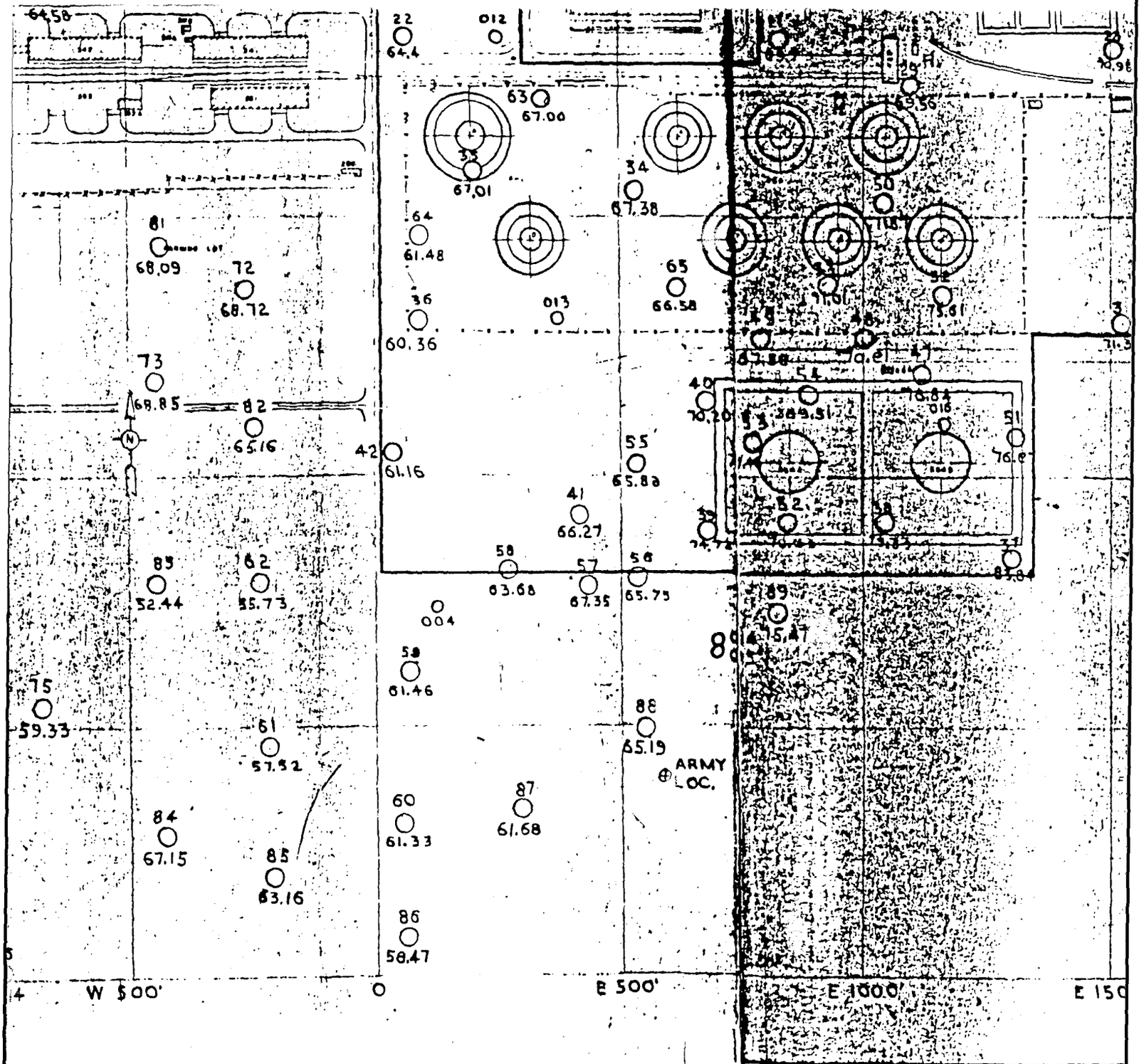
E 1500'
E 2000'
E 2500'
E 3000'
E 3500'
DWG. NO
DESCRIPT
REF. DWGS
T-1566
020
075
7
66.8
8
9
12
67.3
10
11
69.3
27
71.47
19
74.5
017
018
31
71.34
OPEN DITCH
LEGEND
2
HOLE
EXAMPLE
66.2
ELEVATION TOP
3068


E 2500'
E 3000'
E 3500'
N 800'
DWG. NO
DESCRIPTION
REF. DWGS.
N
SECTION 36
SECTION 1
S 500'
S 1000'
S 2000'
020
073
013
017
LEGEND:
HOLE #
EXAMPLE
66.2
ELEVATION TOP PIPE (+5200')

4068


46
57.90
81
68.09
72
68.72
80
62.0
73
68.85
82
74
61.5
N
75
54.06
83
52.44
75
59.33
78
47.46
84
67.15
77
49.87
76
51.14
W 2000'
W 1500'
W 1000'
W 500'

5088



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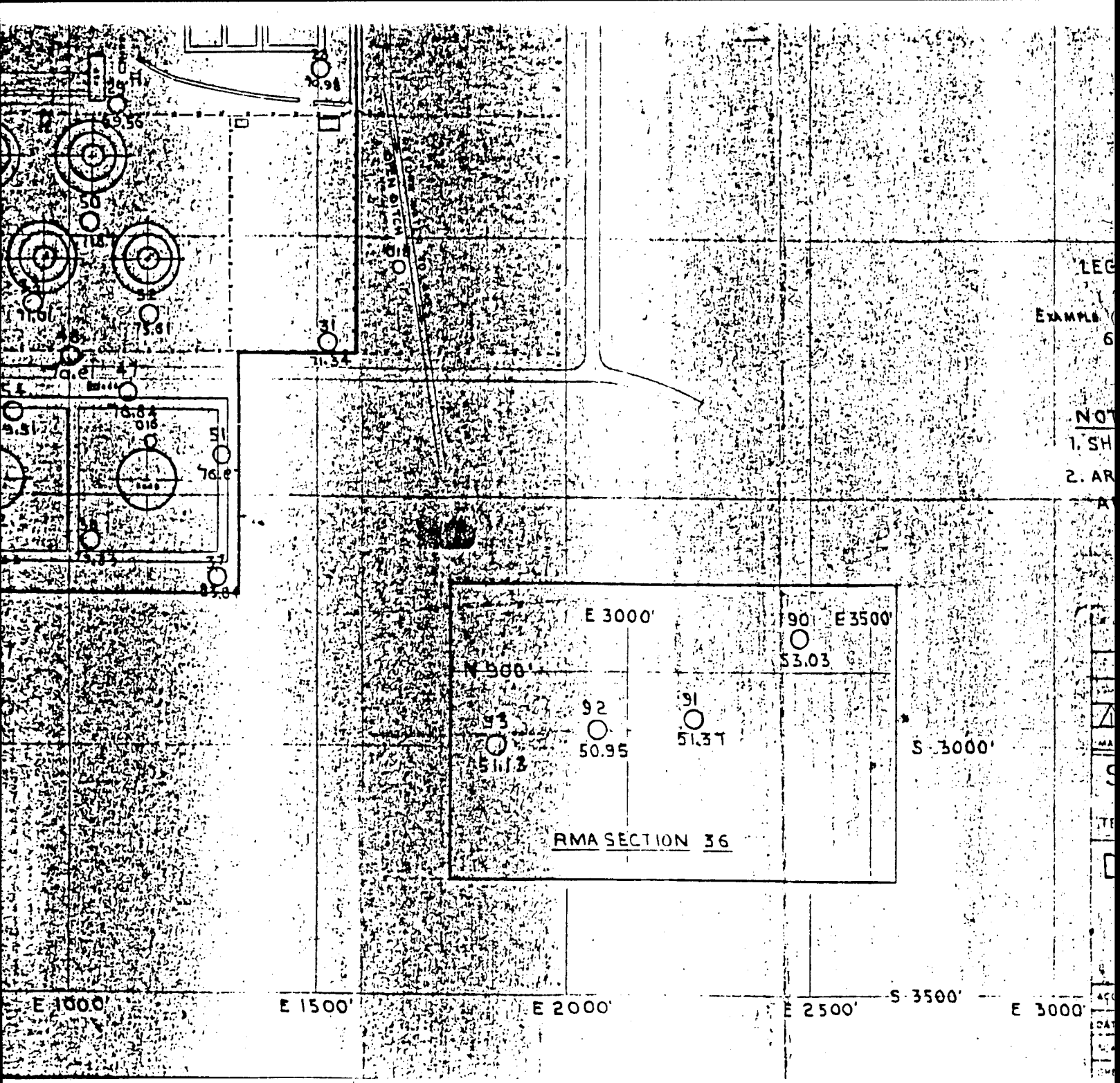
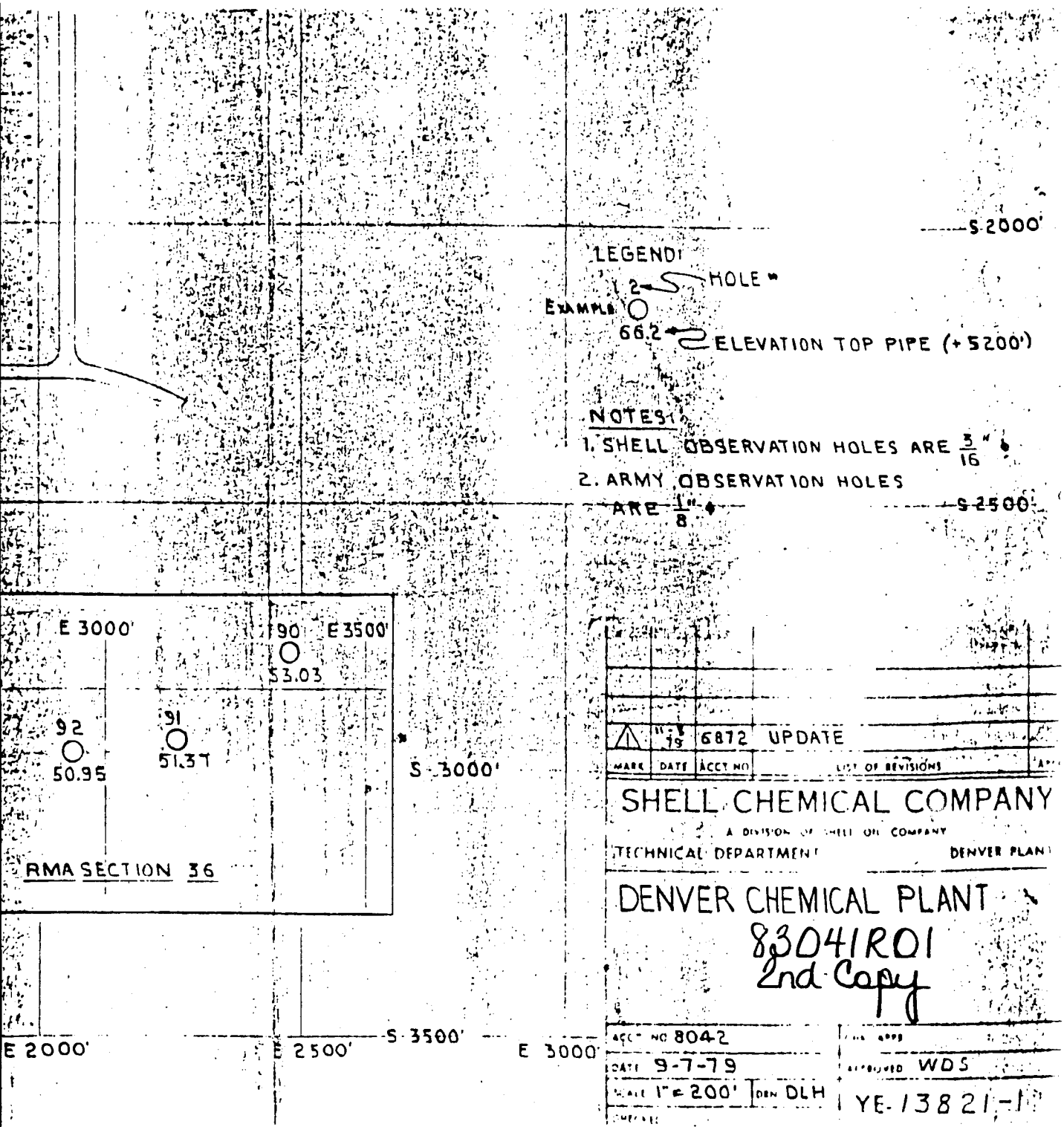

E 3000'
90
E 3500'
53.03
N 500'
92
91
93
50.95
51.37
51.13
S 3000'
RMA SECTION 36
E 1000'
E 1500'
E 2000'
E 2500'
S 3500'
E 3000'

7088



MARK	DATE	ACCT NO	LIST OF REVISIONS	APP
1	11-5-79	6872	UPDATE	

SHELL CHEMICAL COMPANY

A DIVISION OF SHELL OIL COMPANY

TECHNICAL DEPARTMENT — DENVER PLANT

DENVER CHEMICAL PLANT

83041R01

2nd Copy

ACCT NO 8042	APPD
DATE 9-7-79	APPROVED WDS
SCALE 1" = 200' DRN DLH	YE-13821-1

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